Psychologically-Informed Methods of Enhancing Endurance Performance

Alister McCormick

A thesis presented for the degree of
Doctor of Philosophy in Sport and Exercise Science and Sports Therapy

103,200 words

School of Sport and Exercise Sciences
University of Kent
August 2016

Abstract

The main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance, particularly in endurance sport events. There were three main research aims. First, this thesis aimed to synthesise research conducted to date on the psychological determinants of endurance performance. A systematic literature review was conducted to identify psychological interventions that affect endurance performance in experimental research. Learning psychological skills, verbal encouragement, and head-to-head competition enhanced endurance performance, whereas mental fatigue undermined endurance performance. Second, this thesis aimed to inform the design of performance-enhancement psychological interventions for endurance sports. In the first study addressing this aim, focus group interviews were conducted with recreational endurance athletes of various endurance sports, distances, and competitive levels to identify psychological demands that are commonly experienced by endurance athletes. Seven common psychological demands were identified using a thematic analysis. These demands were commonly encountered away from the competitive environment (time investment and lifestyle sacrifices, commitment to training sessions, concerns about optimising training, and exercise sensations during training), preceding an event (pre-event stressors), and during an event (exercise sensations, optimising pacing, and remaining focused despite adversity). Psychological interventions that help endurance athletes to cope with these psychological demands could potentially enhance performance in endurance events. In the second study that aimed to inform the design of an intervention, a psychophysiology experiment applied research on the facial feedback hypothesis to determine whether frowning modulates perception of effort during endurance performance. Contrary to hypotheses, intentionally frowning throughout a cycling time-to-exhaustion test did not influence perception of effort or time to exhaustion. This finding suggests that novel interventions that are informed by the facial feedback hypothesis and that target the expression of a frown would be unlikely to enhance endurance performance. Finally, this thesis aimed to examine the effect of a psychological skills training intervention on performance in a real-life endurance event. A randomised, controlled experiment was conducted to examine the effect of learning motivational self-talk on performance in a 60-mile, overnight ultramarathon. Although performance times indicated that motivational self-talk possibly produced a performance enhancement that might benefit ultramarathon runners, additional data will be collected at the same ultramarathon in 2016 to draw firmer conclusions. Overall, the findings of this thesis draw attention to psychological factors that influence performance in endurance events and demonstrate that psychologically-informed interventions can enhance endurance performance. People involved in endurance sports, such as athletes and coaches, are therefore encouraged to systematically work on the psychological aspects of training, preparing for a competition, and competing. Suggestions for how to approach this practically are scrutinised throughout the thesis.

Acknowledgements

I would like to thank my supervisors, Dr Carla Meijen and Professor Samuele Marcora, for offering me their time and expertise. To borrow words commonly attributed to Beverly Sills, they taught me that there are no shortcuts to any place worth going.

I would like to thank my former colleagues in the School of Sport and Exercise Sciences at the University of Kent for offering suggestions on my research and for providing in-house training. In particular, I would like to thank Dr Kristina Charlotte Dietz (now at the University of Cambridge) for checking the effect sizes reported in the systematic literature review and for independently evaluating the quality of a random selection of studies reported in the systematic literature review. I would also like to specifically thank Dr Benjamin Pageaux (now at the University of Burgundy, Dijon) for providing electromyography training and for being helpful throughout my PhD. I would also like to thank my friends in the School of Sport and Exercise Sciences for their social support.

I would like to thank the University of Kent for the 50th Anniversary Research Scholarship that funded my PhD.

I would like to thank all of the people who offered their time to participate in my research.

I would like to thank my wife Victoria for the sacrifices that she has made for me to complete a PhD and to become a sport and exercise psychologist.

Finally, I would like to thank my daughter Charlotte-Amber for reminding me that, at the end of the day, it is just a PhD.

Table of Contents

List of Tables

List of Figures

Publications and Presentations Based on Thesis Material

Research reported in this thesis has contributed to the following publications and conference presentations.

Peer-reviewed publications:

McCormick, A., Meijen, C., & Marcora, S. (2015). Psychological determinants of whole-body endurance performance. *Sports Medicine*, *45*, 997-1015. doi:10.1007/s40279-015-0319-6

Conference presentations:

McCormick, A., Meijen, C., & Marcora, S. (2015, December). *The effect of motivational self-talk on performance in an ultramarathon*. Paper presented at the British Psychological Society Division of Sport and Exercise Psychology Conference, Leeds, England.

McCormick, A., Meijen, C., & Marcora, S. (2015, September). *The effects of self-talk on performance in an ultramarathon*. Paper presented at the Endurance Research Conference, Kent, England.

McCormick, A., Meijen, C., & Marcora, S. (2015, February). *The effects of self-talk on real-life endurance performance*. Paper presented at the Association for Applied Sport Psychology Student Conference, Loughborough, England.

McCormick, A., Meijen, C., & Marcora, S. (2013, December). *Psychological determinants of endurance performance: A systematic review*. Poster presented at the British Psychological Society Division of Sport and Exercise Psychology Conference, Manchester, England.

Ethical Approval Reference Numbers

Chapters 3, 4, and 5 were ethically approved by the University of Kent School of Sport and Exercise Sciences Research Ethics and Governance Committee.

Table i

Ethical Approval Reference Numbers for Chapters 3, 4, and 5

	Original Ethics Reference Number	Amendment Ethics Reference Number(s)
Chapter 3	Prop 49_2012_13	Prop 72_2012_13
Chapter 4	Prop 06_2014_15	Prop 93_2014_15, Prop 105_2014_2015
Chapter 5	Prop 113_2013_14	Prop 142-2014_2015

Chapter 1

Introduction

Chapter Overview

The main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance, particularly in endurance sport events. As explained in this chapter, endurance performance is defined as performance during whole-body, dynamic exercise that involves continuous effort and lasts for 75 seconds or longer. Many running, swimming, cycling, triathlon, rowing, cross-country skiing, canoeing, and speed-skating events satisfy this definition. Such endurance events are abundant within competitive sport. They are found at the Summer and Winter Olympics, and athletes compete in these events recreationally and professionally. Endurance events are also popular with non-competitive entrants. In 2015, for example, more than 37,000 people finished the London Marathon ("Brasher hails an astonishing day," 2015), and more than 13,000 people participated in the London Triathlon ("The event," n.d.).

The effects of psychological factors on endurance performance were observed as early as 1898 when Norman Triplett presented record performance times for different cycling events. Triplett demonstrated that performance times were 3.5% faster in paced, 25-mile races when cyclists competed against rivals than when these cyclists raced against time only. In other words, the competitive context had a beneficial effect on the performances of these cyclists. Research examining the effects of psychological factors on endurance performance has accumulated during the last 50 years, beginning with Jack Wilmore's research examining the effect of head-to-head competition on cycling time to exhaustion (Wilmore, 1968). Surprisingly, psychological factors that affect endurance performance have not been reviewed systematically in a book chapter, narrative review, systematic literature review, or meta-analysis.

Chapter 1 is a narrative review that "sets the scene" of the thesis by introducing relevant theory and research. First, this chapter offers a definition of endurance performance that will guide the focus of the thesis, and it evaluates experimental measures of endurance performance. Second, this chapter overviews contemporary physiological and psychological theories that offer alternative explanations of how endurance performance is determined. Third, this chapter introduces three psychological theories (cognitive-motivational-relational theory, the Theory of Challenge and Threat States in Athletes, and the facial feedback hypothesis) that can be applied to endurance sports and that informed the studies conducted within the thesis. Finally, this chapter overviews research on psychological factors that influence endurance performance. These psychological factors are contextual variables, accurate and deceptive performance feedback, music, attentional focus, PST, and hypnosis. Sport science terms that are used throughout Chapter 1 are introduced in Table 1 (p. 4).

Table 1
Introduction to Sport Science Terms Used Throughout Chapter 1

Sport science term	Meaning
Aerobic versus anaerobic metabolism	Aerobic and anaerobic metabolism are metabolic processes that produce energy with and without oxygen, respectively (Wilmore, Costill, & Kenney, 2008). The aerobic energy system produces large amounts of energy through the combustion of carbohydrates and fats, but it delivers energy at a slower rate than the anaerobic energy systems. Anaerobic systems are capable of generating energy quickly, but the amount of energy that they can release in a single bout of intense exercise is limited. The relative contribution of the aerobic energy system increases with the duration of maximum-effort, dynamic, whole-body exercise (Gastin, 2001).
Afferent feedback	Nerve impulses that are sent from the peripheral organs (e.g., heart, lungs, exercising locomotor muscles) to the central nervous system, relaying information such as heart rate, temperature, and levels of metabolic by-products.
Central motor drive	Nerve impulses that are sent by the brain to the motor units innervating the exercising muscles to get these muscles to contract.
Critical power / speed	The power or speed that can theoretically be sustained for an indefinite period of time without undue fatigue (e.g., Hill, 1993; A. M. Jones, Vanhatalo, Burnley, Morton, & Poole, 2010).
Economy / efficiency	Economy and efficiency are related concepts that refer to the amount of energy that is used to perform a specific exercise quantity. Specifically, efficiency refers to the quantity of work completed (e.g., on a cycle ergometer) relative to the energy expended, and running economy refers to the volume of oxygen uptake that is needed to run at a given velocity (Bassett & Howley, 2000).
Exhaustion	The point at which an exerciser cannot (or chooses not to) continue. During a time-to-exhaustion test, the point of exhaustion is defined by an inability to maintain power, speed, or cadence (Hopkins, Schabort, & Hawley, 2001).
Fatigue	“An acute impairment of (muscle) performance that includes both an increase in the perceived effort necessary to exert a desired force and an eventual inability to produce this force” (Enoka & Stuart, 1992, p. 1631).
Lactate threshold	The point at which blood lactate begins to accumulate above resting levels during exercise of increasing intensity. At this point, lactate removal is no longer able to able to keep up with lactate production (Wilmore et al., 2008).
Maximum oxygen consumption ($\dot{V}O_{2max}$)	The maximum capacity of the body to consume oxygen during maximal exertion (Wilmore et al., 2008). $\dot{V}O_{2max}$ is predominantly limited by the ability of the cardiorespiratory system to transport oxygen to the muscles (Bassett & Howley, 2000).
Perception of effort / perceived exertion	The conscious sensation of how effortful, heavy, and strenuous the exercise feels (Marcora, 2010a).

Defining and Measuring Endurance Performance

This thesis examines psychologically-informed methods of enhancing endurance performance. Given its central position in the thesis, it would be prudent to begin by articulating what is meant by endurance performance and by introducing established experimental measures of endurance performance. First, this section offers a definition of endurance performance that will determine the scope of the thesis and that will act as an eligibility criterion for the systematic literature review reported in Chapter 2. Second, this section introduces established experimental measures of endurance performance and discusses the choice between two commonly-used measures of endurance performance: time trials and time-to-exhaustion tests.

Defining Endurance Performance

Academics and laypeople are familiar with the terms *endurance*, *endurance events*, and *endurance sports*, and they typically do not need defining. Sport events that require an individual to perform for an extended duration over a long distance are generally called endurance events. These events include single or combined running, cycling, and swimming events (e.g., marathons, ultramarathons, triathlons), rowing, cross-country skiing, canoeing, and speed skating (e.g., Shephard & Åstrand, 2000). For each of these events, however, it is difficult to determine the minimum performance distance or time that qualifies as an endurance event. Furthermore, the sport psychology literature demonstrates that prolonged exercise tasks that are not typically associated with competitive sport, such as sit ups and weight holding, might also be called endurance tasks. The specific tasks, distances, and durations that qualify as measuring endurance performance are therefore debatable. Implicitly, the chosen definition of endurance performance will influence the content of each chapter of the thesis. More explicitly, however, this definition will also act as an eligibility criterion for the systematic literature review reported in Chapter 2, determining the dependent variables that are included within the review. A definition that can be applied with consistency as an eligibility criterion is therefore required.

Sport psychology research on endurance performance can be divided into muscular endurance and aerobic endurance (e.g., Brick, MacIntyre, & Campbell, 2014). Muscular endurance performance has been measured using sit-up (e.g., Bar-Eli, Tenenbaum, Pie, Btesh, & Almog, 1997), leg-raise (e.g., Weinberg, Gould, & Jackson, 1979), hand-grip (e.g., Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008), phantom-chair or skiers-sit (e.g., Feltz & Riessinger, 1990), and weight-holding tasks (e.g., Crust & Clough, 2005). Muscular endurance tasks typically have the following characteristics: they require the exerciser to sustain high-intensity (e.g., a sprint), repetitive (e.g., bench pressing for a weightlifter, jabbing for a boxer), or static exercise (e.g., a wrestler attempting to pin an opponent); they mostly involve a single muscle or muscle group, and fatigue is confined to these muscles; and the duration is typically no more than one or two minutes (Wilmore et al., 2008). In contrast, aerobic or cardiorespiratory endurance refers to "the entire body's ability to sustain prolonged, dynamic exercise using large muscle groups" (Wilmore et al., 2008, p. 223). During prolonged bouts of dynamic exercise, a person's endurance capacity is dependent on the ability of their cardiovascular and respiratory systems to maintain oxygen delivery to the working muscles, as well as the ability of their muscles to utilise energy aerobically (Wilmore et al., 2008). Aerobic endurance tasks include running, cycling, swimming, and rowing.

This thesis focuses on the psychological interventions that affect aerobic endurance performance, and it is therefore interested in the dynamic, whole-body exercise tasks that people perform recreationally and competitively, such as running, cycling, swimming, and rowing. At the upper limit, whole-body endurance events can last multiple days or even weeks. For example, participants in the Tour de France—a cycling stage race—compete for 21 days over a 23-day period. In 2014, they raced over an average of 174 kilometres each day (“Le Tour de France 2014 Route,” n.d.). Further, the longest, certified foot race lasts 52 days, and participants must average nearly 60 miles each day to finish within the time limit (“The Self-Transcendence 3100 Mile Race,” n.d.). The minimum duration or distance at which dynamic, whole-body exercise involves endurance is more difficult to determine.

Depending on the criteria used to define endurance performance, dynamic and whole-body endurance performances could last as little as 30 seconds. Because exercisers cannot sustain maximal effort over a long distance, endurance events are characterised by the need for pacing. In other words, the exercise is sub-maximal. Pacing can be observed in exercise bouts as short as 30 to 45 seconds. Specifically, non-athletes were found to reduce their power output towards the beginning of 30-second and 45-second all-out sprints on a cycle ergometer, compared to sprints lasting five and 15 seconds (Wittekind, Micklewright, & Beneke, 2011). The reductions in peak power output during the 30-second and 45-second sprints were 6% and 12%, respectively. If the threshold of sub-maximal exercise is used to define endurance performance—and assuming that this observation is not specific to non-athletes and cycling tasks—this research suggests that, for elite and sub-elite competitive athletes, running distances of approximately 400 metres and freestyle swimming distances of approximately 100 metres could be classed as endurance distances (based on visual inspection of record performance times, e.g., http://www.bucs.org.uk/). Endurance performance, however, is often associated with longer-duration exercise bouts that rely primarily on energy that is derived from aerobic—as opposed to anaerobic—metabolism. As an example, Burnley and Jones (2007, p. 63) defined endurance events as “athletic events lasting more than approximately 5 min and requiring a substantial and sustained energy transfer from oxidative pathways”. The five-minute threshold used in Burnley and Jones’s definition suggests that running distances of approximately 1,500 metres and greater, and freestyle swimming distances of 400 metres and greater, could be classed as endurance distances. For the purpose of guiding this thesis, a minimum exercise time was chosen that recognises the contribution of the aerobic energy system during endurance performance. The relative contribution of the aerobic energy system increases with the duration of maximum-effort exercise, and the relative contribution of the aerobic energy system generally predominates after 75 seconds of maximum-effort exercise (Gastin, 2001). Endurance performance was therefore defined as performance in whole-body, dynamic exercise that involves continuous effort and lasts for 75 seconds or longer. Using this definition, running events of approximately 800 metres and greater, freestyle swimming events of approximately 200 metres and greater, and equivalent distances in cycling, rowing, and speed skating are examples of endurance events.

Measuring Endurance Performance

There are various methods of measuring endurance performance in laboratory and field settings. The most commonly used protocols are time-to-exhaustion tests and time trials (Currell & Jeukendrup, 2008). Time-to-exhaustion tests (or constant-workload tests) measure the amount of time that a person can perform at a fixed power output or velocity (e.g., 80% of a person's peak power output) before they reach exhaustion. Time trials (or constant-work tests) measure the amount of time that it takes a person to complete a set distance or a fixed amount of work (e.g., time to cycle five kilometres). Additional measures include constant-duration tests and incremental tests. Constant-duration tests measure the distance or the amount of work that a person can complete in a set duration (e.g., distance ran in 30 minutes), and incremental tests measure the highest velocity or power-output increment that a person can reach before exhaustion (Hopkins, Schabort, & Hawley, 2001).

Currell and Jeukendrup (2008) argued that sport performance measures should demonstrate the following three qualities: validity, reliability, and sensitivity. A valid measure closely resembles the simulated performance, a reliable measure provides a similar day-to-day result when no intervention is introduced, and a sensitive measure can detect small but important changes in performance (Currell & Jeukendrup, 2008). Currell and Jeukendrup argued that a time trial is the most appropriate measure for investigating whether an intervention affects endurance performance. These authors demonstrated using reliability data that time trials possess superior reliability compared to time-to-exhaustion tests. Further, they argued that time trials are more valid than time-to-exhaustion tests because performance times in laboratory time trials correlate with performance times in competition time trials (e.g., Russell, Redmann, Ravussin, Hunter, & Larson-Meyer, 2004) and they provide a better physiological simulation of real-life performance (Foster, Green, Snyder, & Thompson, 1993; Palmer, Borghouts, Noakes, & Hawley, 1999). Currell and Jeukendrup also argued that, unlike a time-to-exhaustion test, athletes compete in time trials. This distinction, however, is somewhat oversimplified, because relatively few endurance events are true time trials. During a time trial, athletes perform alone and compete for the fastest time. During most running, cycling, swimming, and triathlon competitions, however, athletes compete head-to-head, and performance outcomes such as qualification or medal winning are determined by an athlete’s finishing position relative to others. Although athletes do not perform until exhaustion, they do often attempt to maintain the pace of their competitors, such as the eventual winner (de Koning et al., 2011; Hanley, 2014). As an example, Hanley (2014) analysed pacing profiles at the senior men’s World Cross Country Championships and showed that most athletes started the race by following the pace set by the leaders. Slower finishers became detached from the leaders by the end of the first of six laps, those who finished in the top 15 stayed with the leaders until halfway, and the medal positions were decided during the final lap. Competitive endurance events can therefore resemble a time-to-exhaustion test.

Although time trials demonstrate superior reliability compared to time-to-exhaustion tests (Currell & Jeukendrup, 2008), these two tests are similar in their sensitivity to factors that affect endurance performance; that is, both tests can detect changes in endurance performance. Specifically, Amann, Hopkins, and Marcora (2008) demonstrated that manipulating the oxygen content of inspired air had a much greater effect on time to exhaustion than performance time in a time trial, and the large effect on time to exhaustion compensated for this test's greater measurement error. Based on these findings, Amann and colleagues argued that sensitivity should not determine whether a researcher chooses a time trial or a time-to-exhaustion test to measure endurance performance. Instead, they suggested that a researcher might select a time trial when it is desirable for participants to choose their own pacing strategy. For example, a researcher may wish to determine whether using a particular cognitive strategy to enhance endurance performance could actually distract the performer from their pacing and therefore have a detrimental effect on endurance performance. On the other hand, time-to-exhaustion tests allow the researcher to fix the performer's workload, which means that physiological and psychological responses to endurance exercise are not influenced by differences in pacing (e.g., starting faster in one performance than another). Time-to-exhaustion tests could therefore be an appropriate choice when comparing the effects of an intervention on physiological responses to exercise (Amann et al., 2008) or when examining an intervention-performance mechanism (Currell & Jeukendrup, 2008). For example, time-to-exhaustion tests could allow a researcher to determine the psychological or physiological mediating variables that cause a psychological intervention to affect endurance performance. The aims of the research should therefore determine the choice between a time-to-exhaustion test and a time trial.

Theoretical Perspectives of Endurance Performance

This thesis examines psychologically-informed methods of enhancing endurance performance. Endurance performance is a multi-disciplinary research area; sport science and sports medicine researchers specialising in a vast range of research areas (e.g., muscle physiology, cell physiology, endocrinology, nutrition, biomechanics) have extensively studied the physiological, genetic, and environmental mechanisms of endurance performance (Shephard & Åstrand, 2000). The purpose of this section is to overview contemporary theories that explain endurance performance. These theories offer alternative accounts of how endurance performance is determined, as well as how psychological factors could—and indeed do—influence endurance performance. Most of these theoretical accounts are physiological or mathematical in nature. In fact, the psychobiological model of endurance performance is the only model based on psychological theory that specifically explains how psychological factors affect endurance performance. These theories are important because they identify variables and processes that could determine the upper limit to an endurance athlete's performance potential. As overviewed later in this chapter, a range of psychological factors may play an important role in determining how well an endurance athlete performs, relative to their performance potential. These influential psychological factors include contextual variables, accurate and deceptive performance feedback, music, attentional focus, PST, and hypnosis.

Two of the theoretical perspectives of endurance performance that are outlined in this section (critical power concept and oxygen uptake kinetics) describe mechanisms that are specific to particular exercise intensities. Essentially, power outputs or velocities that correspond with three key physiological variables (lactate threshold, critical power, and $\dot{V}O_{2max}$) are used to partition four exercise intensity domains (moderate, heavy, severe, and extreme), and exercise at these intensities produces uniform physiological response characteristics across participants (Murgatroyd, Wylde, Cannon, Ward, & Rossiter, 2014). The four exercise intensity domains are summarised in Table 2.

Table 2
Exercise Intensity Domains (Adapted From Burnley & Jones, 2007)

Intensity domain	Lower limit	Upper limit	Estimated time to exhaustion
Moderate		Lactate threshold	> 4 hours
Heavy	Lactate threshold	Critical power	Up to approximately 3-4 hours
Severe	Critical power	Highest power that elicits $\dot{V}O_{2max}$ before exhaustion	Up to approximately 30-45 minutes
Extreme	Highest power that elicits $\dot{V}O_{2max}$ before exhaustion		< 120 seconds

Critical Power Concept

During severe-intensity exercise, time to exhaustion increases in a predictable manner with a decrease in performance power or velocity. A. M. Jones, Vanhatalo, Burnley, Morton, and Poole (2010) argued that two parameters, critical power and *W'*, are sufficient to describe this relationship between power and time to exhaustion. Critical power is the highest power output that can be sustained by aerobic processes without continuously drawing on *W'*, and *W'* is a finite amount of work, principally derived from anaerobic processes, that can be completed during exercise above the critical power. Exercisers can perform at their critical power or velocity for an indefinite amount of time without undue fatigue. When exercising above the critical power, however, *W'* is progressively reduced, and the exerciser reaches exhaustion when *W'* is depleted. Critical power and *W'* can be used to predict performance time in a time-to-exhaustion test, as well as mathematically-optimal pacing strategies for a time trial. Indeed, A. M. Jones and colleagues suggested that an infinite number of pacing strategies could produce an optimal performance time in a time trial, as long as the performance power/velocity does not drop below the critical power/velocity. This theoretical perspective suggests that exhaustion in a time-to-exhaustion test is ultimately involuntary, assuming that participants are motivated to push themselves to their physical capacity and deplete *W'*. Although this theory explains endurance performance from a physiological and mathematical perspective, pacing decision making, concentration on pace, and motivation are psychological factors that this theory implies could determine whether performers achieve their physiological potential during severe-intensity endurance exercise.

$\dot{V}O_{2max}$, Lactate Threshold, and Economy/Efficiency

Maximum oxygen consumption ($\dot{V}O_{2max}$), the lactate threshold, and economy/efficiency are central variables in exercise physiology. They are parameters of aerobic fitness, and they are therefore frequently-chosen outcome variables in endurance training studies (A. M. Jones & Carter, 2000). They are determined by physiological variables such as muscle capillary density, maximum heart rate, stroke volume, haemoglobin content, aerobic enzyme activity, muscle fibre type, and anthropometry and elasticity (Joyner & Coyle, 2008). Numerous researchers (e.g., Bassett & Howley, 2000; Joyner & Coyle, 2008) argue that $\dot{V}O_{2max}$, the lactate threshold, and economy/efficiency are the most important physiological determinants of endurance performance.

Bassett and Howley (2000) and Joyner and Coyle (2008) argued that $\dot{V}O_{2max}$, the lactate threshold, and efficiency play key roles in determining endurance performance. These researchers argued that $\dot{V}O_{2max}$ and the lactate threshold interact to determine the *performance* $\dot{V}O_2$, which is the oxygen consumption at the lactate threshold. The performance $\dot{V}O_2$ represents the amount of oxygen consumption that can be sustained for a prolonged period of time, such as during a marathon, without accumulation of lactate. Further, performance $\dot{V}O_2$ interacts with efficiency to determine the speed or power that can be generated when consuming this amount of oxygen. In other words, efficiency determines how effectively energy produced at the lactate threshold is translated into actual work. From this theoretical perspective, $\dot{V}O_{2max}$, the lactate threshold, and efficiency interact to determine the highest velocity or power that an endurance athlete can sustain during an event, and this velocity or power is a strong predictor of endurance performance (Farrell, Wilmore, Coyle, Billing, & Costill, 1979). Indeed, Bassett and Howley argued that velocity at the lactate threshold is the best physiological predictor of distance-running performance.

Applying this theoretical perspective, psychological interventions that improve economy of movement should have a beneficial effect on endurance performance. Studies have examined the effects of psychological factors on running economy. For example, runners demonstrated superior running economy when they focused their attention externally compared to internally (Schücker, Anheier, Hagemann, Strauss, & Völker, 2013; Schücker, Hagemann, Strauss, & Völker, 2009), and running economy improved when runners were given false positive feedback about the economy of their running style (Stoate, Wulf, & Lewthwaite, 2012). These studies did not measure endurance performance, however. Psychological interventions could also enhance endurance performance indirectly if they help exercisers adhere to training programmes intended to increase $\dot{V}O_{2max}$, the lactate threshold, or economy of movement, such as high-intensity interval training (Esfarjani & Laursen, 2007) or maximal strength training (Støren, Helgerud, Støa, & Hoff, 2008). For example, goal-setting interventions could have a beneficial effect on training adherence and therefore parameters of aerobic fitness. Indeed, Wilson and Brookfield (2009) demonstrated that working towards process goals (e.g., "maintain your heart rate above 140 beats per minute for 30 minutes of your 40-minute session" or "drive with the legs on the rowing ergometer") increased recreational exercisers' adherence to a six-week exercise programme, compared to outcome goals (e.g., "lose four kilograms in six weeks") and a no-intervention control.

In addition to running velocity at the lactate threshold, Bassett and Howley (2000) recognised that other factors contribute to endurance performance; these authors stated, "If any model could explain all of the variance in performance, gold medals would be handed out in the lab" (p. 80). Interestingly, Bassett and Howley reported that each of their key physiological variables correlate with performance most strongly when the sample is heterogeneous with respect to the particular physiological variable and performance level; each of these variables becomes less useful at predicting performance when the sample is homogeneous (e.g., all elite-level athletes with similar $\dot{V}O_{2max}$ values). Although Bassett and Howley did not refer to psychology, psychological variables could be among the other variables that separate endurance athletes of similar ability and contribute to performance outcome. Although they did not specify the contributing factors, Joyner and Coyle (2008, p. 35) similarly cautioned that "complex motivational and sociological factors also play important roles in who does or does not become a champion and these factors go far beyond simple physiological explanations". As physiological variables cannot fully account for endurance performance in isolation, it is important to take a holistic approach to understanding endurance performance and to appreciate the roles of physiological factors and also influential psychological factors such as contextual variables, music, PST strategies.

Oxygen Uptake Kinetics

In contrast to the views of Bassett and Howley (2000) and Joyner and Coyle (2008), Burnley and Jones (2007) argued that $\dot{V}O_{2max}$, the lactate threshold, efficiency/economy, and critical power do not directly determine endurance performance. Instead, they argued that these parameters of aerobic fitness are important because of their effect on the body's oxygen-uptake response to exercise—referred to as *oxygen uptake kinetics*—which determines endurance performance in the heavy and severe exercise domains (see Table 2, p. 12, for the exercise intensity domains). Specifically, oxygen uptake increases following the onset of exercise, and continuous exercise at each of the four exercise intensities is characterised by a typical pattern of oxygen uptake across time. During exercise, it is desirable for the body to adapt to the onset of exercise quickly and demonstrate a fast oxygen-uptake response that leads to achievement of an oxygen steady-state as soon as possible. During exercise at heavy and severe intensities, however, oxygen uptake continues to slowly increase above the level that might be anticipated for the exerciser's work rate (i.e., the anticipated steady-state). This *slow component* is debilitative to endurance performance, because its presence means that the energy demand of exercising is increasing. Interventions such as training, warm-up exercise, pacing strategies, and nutritional interventions that cause a faster oxygen uptake response at the start of exercise or reduce the magnitude of the slow component can reduce fatigue development and therefore enhance endurance performance (A. M. Jones & Burnley, 2009). This theoretical perspective specifically focuses on physiological aspects of endurance performance, and the role of psychological factors is not explained. Nevertheless, the theory explains that an athlete's performance potential is determined by their oxygen uptake kinetics, and it is reasonable to suggest that psychological factors such as the athlete's level of motivation and psychological skills could affect their willingness or ability to perform close to this performance potential.

Equations for Predicting Endurance Performance

Variables that influence, or at least correlate with, endurance performance (e.g., $\dot{V}O_{2max}$) have been included in mathematical equations to predict endurance performance. Mathematical models of cycling (e.g., Capelli et al., 1998; Olds, Norton, & Craig, 1993), running (e.g., di Prampero, 2003), and rowing performance (e.g., Ingham, Whyte, Jones, & Nevill, 2002) predict performance with a high degree of accuracy based on physiological, biomechanical, anthropometric, and environmental variables. Whereas some researchers (e.g., Capelli et al., 1998) do not refer to psychological factors that could influence performance (e.g., how motivated people are), others suggest that psychological factors might account for the error in calculations because they "cannot easily be modeled" (Olds et al., 1993, p. 734), or they imply that psychological factors might be among the factors that prevent an athlete from reaching their theoretical best performance time (di Prampero, 2003).

Y. O. Schumacher and Mueller (2002) demonstrated the utility of mathematical models to sport science application in a team-pursuit, track-cycling context. They used a mathematical formula to predict the performance time that would set a new world record at an upcoming Olympics, and they calculated the average power output that every team member would need to achieve to attain this time. Y. O. Schumacher and Mueller estimated that several combinations of the Olympic athletes would be able to achieve this time with suitable training. The sport science team carefully planned and implemented the track team's approach to training and competition using sport science theory and relevant mathematical models, and the team achieved the predicted time at the Olympics. Biomechanical, physiological, and anthropometric factors were taken into consideration, but it was somewhat assumed that the athletes would have the psychological skills required to perform close to their potential at the Olympic Games.

Inhibitory Afferent Feedback Model

Amann and colleagues (Amann & Dempsey, 2009; Amann, Proctor, Sebranek, Pegelow, & Dempsey, 2009) argued that an inhibitory afferent feedback model explains performance during high-intensity endurance exercise. Specifically, they proposed that the brain regulates central motor drive to ensure that the development of peripheral locomotor muscle fatigue is restricted to a person-specific critical threshold. In other words, the brain regulates the force produced by the muscles responsible for movement (e.g., the legs) in order to limit muscle fatigue. The development of muscle fatigue is associated with an increase in afferent feedback from these muscles to the central nervous system (CNS), and these authors argue that this afferent feedback has an inhibitory effect on the magnitude of central motor drive. In other words, the brain will reduce the force produced by the leg muscles as these muscles tire. Once muscle fatigue reaches the person-specific threshold, the exerciser will either terminate the exercise (e.g., stop performing a time-to-exhaustion test) or they will drastically reduce their exercise intensity (e.g., they will reduce their pace or power output during a time trial). By regulating central motor drive, the CNS allows the exerciser to avoid intolerable levels of effort and pain, avoid severe muscle dysfunction, and preserve a functional muscle reserve for after exhaustion.

Similar to the preceding physiological explanations of endurance performance, the inhibitory afferent feedback model does not dispute that psychological factors affect endurance performance. Indeed, Amann and Secher (2010) suggested that psychological factors contribute towards time-trial performance by influencing the magnitude of central motor drive. Nevertheless, these physiological perspectives do not explain how physiological and psychological factors interact to determine endurance performance. The central governor model and the psychobiological model of endurance performance are introduced next. These models adopt holistic approaches to understanding endurance performance, and they explain how a wide range of physiological and psychological factors interact to determine endurance performance.

Central Governor Model

The central governor model (Noakes, 2012) proposes that a "governor" in the CNS continuously modifies the number of motor units (muscle fibres) that are recruited in the exercising limbs, or terminates exercise altogether, to protect the body from a catastrophic disruption to homeostasis. In other words, this central governor adjusts an exerciser's work rate to protect them from harm. During a time-to-exhaustion test, the central governor terminates exercise before a catastrophic disruption to homeostasis occurs. During a time trial or constant-duration test, the central governor ensures that the exerciser stays within their physiological limits throughout the exercise bout by continuously adjusting the exerciser's pace or power output. Specifically, the central governor restricts an exerciser's starting pace to a pace that it anticipates can be sustained for the expected duration of the exercise bout. Psychological factors such as self-belief, emotional state, and level of motivation are among the wide range of psychological and physiological factors that can influence this "sustainable" work rate. The central governor then continuously adjusts motor recruitment, based on the relative amount of exercise remaining and afferent feedback from different physiological systems, to ensure that the work rate can be sustained without causing harm. Importantly, the central governor model suggests that exercisers perform with an accessible "reserve" of motor units. The central governor, however, uses unpleasant sensations of fatigue as a protective mechanism to ensure that the exercise intensity and duration stay within the exerciser's physiological limit. Psychological interventions such as PST could enhance endurance performance if they allow the performer to access the reserve of motor units and perform closer to their physiological limit, either by reducing unpleasant exercise sensations or by increasing the performer's tolerance of them (Mauger, Jones, & Williams, 2010). In other words, psychological interventions could allow an exerciser to override the central governor and perform for longer in a time-to-exhaustion test or perform faster in a time trial.

The central governor model proposes that perception of effort plays a crucial role in preventing bodily harm. According to the anticipatory feedback model (Tucker, 2009), which is based on the central governor model, volitional exhaustion occurs during endurance exercise when perception of effort reaches levels that are intolerably high or uncomfortable, and this intolerable level precedes potentially-harmful threats to homeostasis. When endurance performance is assessed through a time-to-exhaustion test, the anticipatory feedback model suggests that a “central controller” in the brain—akin to the central governor—subconsciously anticipates the duration of exercise that can be safely completed at the onset of exercise, and then uses this prediction to set an initial rate of increase in perception of effort. Throughout the exercise bout, the central controller then continuously uses afferent feedback from different physiological systems to adjust the rate of increase in perception of effort so that the maximum-tolerable perception of effort, and therefore termination of exercise, coincides with a duration that does not pass the body’s safe physiological limit. During a time trial, however, exercisers can reduce their work rate if their perception of effort is too high to be sustained. According to the anticipatory feedback model, the exerciser will start at a work rate that the central controller anticipates is optimal for the performance distance or duration. The central controller then uses feedback from physiological systems to generate a conscious perception of effort that is continuously compared to a subconscious perception of effort “template”. This template anticipates an optimal perception of effort for each stage of the exercise bout, based on previous experience and knowledge of the exercise duration. Throughout the time trial, the central controller adjusts the exerciser’s work rate so that their conscious perception of effort increases in line with the perception of effort template, which allows the exerciser to reach the maximum-tolerable perception of effort at the completion of the exercise bout and therefore avoid premature exhaustion.

The central governor model explains how a wide range of physiological and psychological factors interact to determine endurance performance. However, the plausibility of a central governor has been challenged. In particular, Shephard (2009) challenged five corollaries of the central governor model. Specifically, Shephard argued that there is a lack of strong evidence for the existence of selective evolutionary pressures that would favour the evolution of a central governor in humans. He also reasoned that if a central governor exists, then its effectiveness at protecting the body from hazards such as hyperthermia (elevated body temperature), myocardial ischaemia (insufficient blood flow to the heart muscle), and pulmonary hypertension (raised blood pressure in the vessels that supply the lungs) is limited, as evidenced by the prevalence of death and harm (e.g., heart attacks, hyperthermia) attributable to exercise (e.g., Kerr, Casa, Marshall, & Comstock, 2013). Furthermore, Shephard argued that research demonstrating that cardiac output and oxygen consumption plateau during intense endurance exercise, and that a person can increase their central motor drive after oxygen consumption has plateaued, are inconsistent with corollaries of the central governor model. Proponents of the central governor model have argued that the lack of experimental evidence for the central governor model could be attributed to the complexity of the physiological, neurological, and psychological interactions that the central governor model proposes, as well as the methodological challenges associated with testing a complex model (Micklewright & Parry, 2010). However, it is questionable whether this complexity prevents the central governor model from being falsifiable (Shephard's reply in Micklewright & Parry, 2010), which is a central characteristic of scientific claims (Popper, 1959).

In addition to the concerns expressed by Shephard (2009), Marcora (2008) argued that the central governor model is internally inconsistent, biologically implausible, and unnecessarily complex. Specifically, Marcora (2008) argued that a central governor should not need to use conscious sensations of fatigue to deter the exerciser from exceeding their physiological limit because this same central governor directly controls the recruitment of exercising muscle. Further, Marcora (2008) expressed concern about the unsubstantiated biological mechanisms. Moreover, Marcora (2007, 2008) argued that the psychobiological model of endurance performance explains research observations equally well without relying on unproven assumptions such as the existence of subconscious central governors or perception of effort templates.

Psychobiological Model of Endurance Performance

The psychobiological model argues that endurance performance can be explained completely by psychological constructs, although it assumes that these psychological constructs have underlying neurobiological processes in the brain (Marcora, 2010a). Based on motivational intensity theory (Brehm & Self, 1989), the psychobiological model argues that perception of effort and potential motivation are the main determinants of endurance performance. Perception of effort is the conscious sensation of how effortful, heavy, and strenuous the exercise feels (Marcora, 2010a), and it reflects a person’s conscious awareness of the central motor commands sent to the locomotor and respiratory muscles (Marcora, 2009). Potential motivation is the greatest amount of effort that a person would be willing to offer to satisfy a motive (Wright, 2008). The magnitude of potential motivation is determined by factors traditionally associated with motive strength such as a person’s needs (e.g., physiological needs, psychological needs), potential outcomes of an instrumental behaviour (e.g., perceived incentive value, experience of pain), and the perceived probability that a successfully-executed behaviour will satisfy a need or produce a desired outcome (Brehm & Self, 1989). When applied to sport and exercise, an athlete would be willing to offer a greater amount of effort (i.e., their potential motivation would be greater) when competing in a higher-level competition such as the Olympic Games (Marcora, 2010a) and when they perceive their goals to be attainable. As a point of clarification, the psychobiological model does not argue that physiological factors such as $\dot{V}O_{2max}$ do not influence endurance performance. It does, however, argue that they are mainly influential through their effect on perception of effort. For example, if an athlete increases their $\dot{V}O_{2max}$ through a training intervention then, when performing the same workload, they would be likely to report lower perceived effort post-intervention than pre-intervention.

According to the psychobiological model, a person's perception of effort and potential motivation comprehensively explain their endurance performance at a fixed workload. A person's perception of effort and potential motivation also explain their endurance performance in time trials performed alone, as long as the performer knows the total performance time or distance, knows the relative performance time or distance completed, and has previous experience performing exercise of varying intensities and durations (Marcora, 2010a). During head-to-head competitions, additional psychological factors contribute to performance due to the tactical nature of the competitions.

When performing at a fixed workload, such as during a time-to-exhaustion test, perception of effort gradually increases with time. In other words, performing at the same workload feels increasingly strenuous. The psychobiological model predicts that people will disengage from the task and consciously decide to stop exercising (they "give up") under one of two circumstances. First, they could decide to stop when their perception of effort has increased to the critical level set by their potential motivation. In other words, the effort required to continue is greater than they are willing to offer.

Second, they could decide to stop because they believe they have offered their maximal effort and perceive continuing as being beyond their capability (Marcora & Staiano, 2010; Smirmaul, Dantas, Nakamura, & Pereira, 2013). In other words, performance at a fixed workload is not directly determined by physiological factors such as muscle fatigue. Instead, performers make a deliberate, conscious decision to stop exercising based on their perception of effort (Marcora & Staiano, 2010).

During endurance competitions such as time trials and head-to-head-competitions, however, athletes are able to adjust their pace. The psychobiological model argues that endurance athletes consciously make pacing decisions to control the increase in their perception of effort over time, so that they experience their maximal level of effort at the end of the event. If perception of effort is low for the stage of an event, endurance athletes can choose to increase their pace without risking premature exhaustion; if perception of effort is high for the stage of the time trial, endurance athletes are likely to reduce their pace to avoid premature exhaustion (Marcora, 2010a; Smirmaul et al., 2013). Indeed, perception of effort and the relative amount of the distance remaining have been shown to predict changes in pace during time trials (de Koning et al., 2011). Further, if an athlete is more highly motivated at a particular endurance event, then they will be willing to experience greater perceived effort at the end of the event. They can therefore choose to perform at a faster pace during the event, as they are willing to tolerate the consequent increase in their perception of effort. Of course, most endurance competitions involve head-to-head competition, and so additional psychological factors influence performance in them. For example, the decisions that endurance athletes make about their pace in competitions will be influenced by individual and team strategy and the behaviour of other competitors (Marcora, 2015).

The experimental predictions of the psychobiological model will be considered in this thesis. In particular, the psychobiological model predicts that any psychological intervention that reduces perception of effort or increases potential motivation will enhance endurance performance, and any intervention that increases perception of effort or reduces potential motivation will undermine endurance performance, even when the person's physiological capacity to perform endurance exercise is unchanged (Marcora et al., 2008). Furthermore, the psychobiological model predicts that all psychological and physiological interventions that affect endurance performance do so because they affect either perception of effort or potential motivation (Marcora, 2010b). Chapter 2 (systematic literature review) will examine whether potential motivation and perception of effort mediate the effects of psychological interventions on endurance performance. The findings of this thesis will be used to critique the psychobiological model in the General Discussion section (pp. 195-200 and pp. 203-204).

Summary

A range of theoretical perspectives offer different explanations of how endurance performance is determined. These theoretical perspectives are mostly grounded in exercise physiology, and they suggest that physiological variables such as $\dot{V}O_{2max}$, the lactate threshold, and efficiency (Bassett & Howley, 2000; Joyner & Coyle, 2008), or physiological processes such as oxygen uptake kinetics (Burnley & Jones, 2007; A. M. Jones & Burnley, 2009), are the main determinants of endurance performance. Across the theories, there appears to be agreement that an athlete's physiology determines the upper limit of their performance potential. Exercise physiology theories suggest that physiological factors directly determine this upper limit, whereas the psychobiological model suggests that influential physiological factors operate through their effect on perception of effort. Within the context of these theories, psychological factors such as motivation, PST, and pacing decision-making may influence how close an athlete performs to their performance potential.

Psychological Theories Informing the Thesis

The psychobiological model is the only model based on psychological theory that specifically explains how psychological factors influence endurance performance. Nevertheless, other psychological theories explain sport performance and can be applied to endurance sports. In this section, three psychological theories that informed the studies conducted within the thesis (cognitive-motivational-relational theory, the Theory of Challenge and Threat States in Athletes, and the facial feedback hypothesis) are overviewed.

Cognitive-Motivational-Relational Theory

Athletes in all sports encounter a wide range environmental demands (events, situations, and conditions), which are referred to as *stressors* (Fletcher, Hanton, & Mellalieu, 2006). These stressors can be broadly categorised as being associated with competitive performance (referred to as "competitive stressors"), the sport organisation that athletes operate within (referred to as "organisational stressors"), and personal life events outside of sport (referred to as "personal stressors"). Competitive stressors include preparation, injuries, pressure to perform well, underperformance in competition, performance expectations, self-presentation, and rivalry. Organisational stressors include leadership and personnel issues, cultural and team issues, logistical and environmental issues, and performance and personal issues. Personal stressors include the work-life interface, family issues, and the death of a significant other (Arnold & Fletcher, 2012; Sarkar & Fletcher, 2014). Some stressors, such as pressure to perform well, are experienced by most samples of athletes (McKay, Niven, Lavallee, & White, 2008; Noblet & Gifford, 2002; Thelwell, Weston, & Greenlees, 2007). Other stressors, however, are particularly prominent in certain samples of athletes, such as certain types of sport (McKay et al., 2008), competitive levels (Fletcher, Hanton, Mellalieu, & Neil, 2012), and playing positions (Thelwell et al., 2007).

Research has illuminated some of the stressors that are experienced by endurance athletes. For international-level cross-country runners, the most frequently-reported stressors during training were related to fatigue, the environment, injury, and training itself, whereas the most reported stressors in competition were related to ability, outcome, tactics/technique, and the environment (Nicholls, Levy, Grice, & Polman, 2009). For runners who ran distances of half-marathon and greater, pain, weather, traffic, and wild animals were stressors encountered during training runs (Samson, Simpson, Kamphoff, & Langlier, 2015). For ultramarathon runners in a 125-kilometre ultramarathon, key stressors during the event were muscle cramping and injuries, gastrointestinal problems, and thoughts about quitting (Holt, Lee, Kim, & Klein, 2014). For channel swimmers, the main stressors during the swim were wildlife encounters, weather and tidal conditions, swimming into the dark, loneliness, uncertainty about the duration of the swim and finishing, and a range of uncomfortable experiences (cold, cramping, pain, aching, hunger, fatigue, mouth swelling, and vomiting) (Hollander & Acevedo, 2000; J. M. Schumacher, Becker, & Wiersma, 2016). Finally, "hitting the wall" is a stressor commonly experienced by recreational marathon runners (Buman, Omli, Giacobbi, & Brewer, 2008). How an athlete appraises stressors, and how well they cope with them, can influence an athlete's emotions, concentration, motivation, and ultimately their sport performance (Lazarus, 2000).

Cognitive-motivational-relational (CMR) theory (Lazarus, 1999, 2000) explains how cognitive appraisals and coping strategies influence an athlete's response to encountered stressors. According to CMR theory, the type and intensity of emotions that an athlete experiences are determined by how they appraise, or evaluate, the significance of their relationship with their environment (i.e., stressors) to their personal wellbeing (Martinent & Ferrand, 2015; Uphill & Jones, 2007). This process of appraisal involves an evaluation of whether the encounter is relevant to their goals, values, beliefs, and situational intentions (primary appraisal) and an evaluation of their coping options (secondary appraisal) (Fletcher et al., 2006). When an athlete encounters a stressor that puts something important at stake (primary appraisal) and does not believe that they can cope (secondary appraisal), they are likely to experience negatively-toned emotions. For example, an ultramarathon runner may get an injury that could prevent them from taking part in an event that they wish to participate in, or a triathlete may get a puncture that could stop them from achieving a personal best or qualification time. In addition to appraisals, the emotions that a person experiences are determined by a coping process that operates throughout an emotional encounter. People use a variety of coping strategies to regulate their emotions. For example, problem-focused coping strategies intend to alter the stressful situation (e.g., repairing a puncture), and emotion-focused coping strategies intend to alter the elicited emotion (e.g., deep breathing to reduce anxiety) (Lazarus, 1999). The coping strategies used by endurance athletes have been highlighted in many studies (e.g., Buman et al., 2008; Hammermeister & Burton, 2001; Nicholls et al., 2009; Stanley, Lane, Beedie, Friesen, & Devonport, 2012). How an athlete appraises and copes with the stressors they encounter are important, because negatively-toned emotions can cause athletes to focus on task-irrelevant cues (e.g., an argument with family) instead of task-relevant cues during training (e.g., process goals) and competition (e.g., pacing cues). Negatively-toned emotions can also undermine motivation for both training and competition (Dugdale, Eklund, & Gordon, 2002; Martinent & Ferrand, 2009; Vast, Young, & Thomas, 2010). An endurance athlete's responses to encountered stressors therefore have the potential to impact on their performance.

This section highlighted the application of CMR theory to endurance sports and highlighted the potential for stressors, appraisals, and coping to influence endurance performance. CMR theory did not directly inform the design of the studies within this thesis. Nevertheless, in Chapter 3, it provided a useful theoretical framework for interpreting the perceived effects of reported psychological demands on endurance athletes' emotions, concentration, motivation, and performance.

Theory of Challenge and Threat States in Athletes

When the outcome of a competition is important to an athlete, the athlete may respond positively and see the competition as a challenge. Alternatively, the athlete may respond negatively and see the competition as a threat. These alternative responses are determined by the athlete's perception of the competition. If the athlete appraises their coping resources as sufficient for the demands of the competition, they are likely to experience a challenge state; if the athlete appraises their coping resources as insufficient for the demands of the competition, they are likely to experience a threat state (M. Jones, Meijen, McCarthy, & Sheffield, 2009). Challenge states are suggested to be beneficial to athletes across sports, because they reduce mentally-draining self-regulation of psychological states, encourage positively-toned emotions, improve decision making (e.g., pacing decision making), facilitate attention to task-relevant cues (e.g., competitor behaviour, navigation cues), support sustained effort, and optimise performance (M. Jones et al., 2009). Indeed, challenge states are consistently associated with more desirable outcomes, including superior sport performance (e.g., Moore, Vine, Wilson, & Freeman, 2012; Moore, Wilson, Vine, Coussens, & Freeman, 2013). Perceiving an endurance event as a challenge is therefore likely to be beneficial to the performance of an endurance athlete.

The Theory of Challenge and Threat States in Athletes proposes that three inter-related psychological constructs comprise the resource appraisals and therefore influence whether athletes experience challenge or threat states in response to competition. These psychological constructs are self-efficacy (judgments of what an individual can accomplish with their skills, Bandura, 1986), perceptions of control (whether an athlete perceives having sufficient control to display their skills for coping with competition demands), and achievement goals. Specifically, an athlete is more likely to experience a challenge state if they possess high self-efficacy, possess perceptions of control, and strive towards achieving competence (rather than striving to avoid incompetence) (M. Jones et al., 2009). Interventions that increase self-efficacy, increase perceptions of control, and encourage athletes to strive towards achieving goals such as a finishing an ultramarathon, achieving a particular time (e.g., a personal best), or placing well relative to others, could be beneficial for endurance performance.

The Theory of Challenge and Threat States in Athletes informed the design of Chapter 5, which examined the effect of learning to use motivational self-talk on performance in an ultramarathon. Learning a psychological skill such as self-talk before an endurance event such as an ultramarathon could increase an endurance athlete's belief that they have the psychological skills necessary to cope with event stressors and achieve their goal (i.e., self-efficacy), and ensure that they perceive themselves as having sufficient control over their ability to display those skills (i.e., perceived control). Chapter 5 examined whether learning to use motivational self-talk increased pre-event self-efficacy and perceived control, which are associated with a challenge state.

Facial Feedback Hypothesis

The facial feedback hypothesis is a theory of emotion that proposes that afferent feedback from facial expressions play a causal role in the experience of emotions (Niedenthal, Barsalou, Ric, & Krauth-Gruber, 2005). It proposes that facial expressions do not simply express emotions, but instead influence whether an emotion is experienced and how intense the emotion is. There are different versions of the facial feedback hypothesis (necessity hypothesis, sufficiency hypothesis, modulation hypothesis) that make different claims about the importance of facial feedback in emotional experience (Davis, Senghas, & Ochsner, 2009). The *necessity hypothesis* proposes that without facial feedback there can be no emotional experience. For example, a person must smile to experience happiness. The necessary hypothesis, however, is inconsistent with evidence that a person with bilateral facial paralysis, who is therefore unable to convey emotions through facial expressions, can demonstrate typical emotional responses to emotionally-evocative photographs (Keillor, Barrett, Crucian, Kortenkamp, & Heilman, 2002). The *sufficiency hypothesis* proposes that performing a facial expression is sufficient to elicit a congruent emotional experience. For example, Lewis (2012, Experiment 1) demonstrated that asking people to lower their eyebrows was sufficient to induce more negative mood states. The *modulation hypothesis* proposes that congruent facial expressions act like “dimmer switches” that modulate (i.e., amplify or soften) emotional experiences that are elicited by external stimuli (Davis, Senghas, & Ochsner, 2009; Niedenthal et al., 2005). The modulation hypothesis is particularly relevant to endurance performance, because performing endurance exercise causes changes in affective states and perception of effort (e.g., Ekkekakis, Parfitt, & Petruzzello, 2011; Noble & Noble, 2000), which could potentially be modulated by congruent facial expressions. There is experimental support for the modulation version of the facial feedback hypothesis. Studies have compared conditions that subtly encourage congruent facial expressions when experiencing emotional stimuli (e.g., a smile when perceiving positively-toned stimuli) with conditions that either do not encourage congruent facial expressions or that actively inhibit them. For example, an influential study by Strack, Martin, and Stepper (1988) demonstrated that people rated cartoons as funnier when they held a pen in their teeth, compared to people who held a pen in their mouths or non-dominant hand. Holding a pen in their teeth facilitated muscular activity involved in a smile, which appeared to modulate their emotional response to the cartoons (holding a pen in their mouths inhibited these muscles). Similarly, subtly encouraging people to furrow their brow, which produces a facial pattern associated with sadness, led to them feeling sadder while they viewed aversive photographs (Larsen, Kasimatis, & Frey, 1992). More recently, studies have examined the effect of receiving botulinum toxin (Botox) injections in the brow region, as the brow region contributes to the expression of negatively-toned emotions (Heckmann, Teichmann, Schroder, Sprengelmeyer, & Ceballos-Baumann, 2003). Botox temporarily paralyses facial muscles in the brow region and prevents afferent feedback from them. For example, botox injections to the brow region have been shown to reduce patients' symptoms of major depression (Wollmer et al., 2012), indicating that brow-region facial musculature plays a role in regulating mood.

Perception of effort is proposed to be one of the main determinants of endurance performance (Marcora & Staiano, 2010), and it is associated with frowning. When people are experiencing high amounts of effort, they tend to frown more. This is captured by a validated pictorial ratings of perceived exertion scale that represents effort using faces that are frowning to varying degrees (Huang & Chiou, 2013). There is experimental support for the association between frowning and perception of effort during endurance performance (de Morree & Marcora, 2012; Huang, Chou, Chen, & Chiou, 2014). For example, muscle activity in the corrugator supercilii muscles, which contract to cause a frown, correlates with ratings of perceived exertion during a cycling time-to-exhaustion test (de Morree & Marcora, 2012). Research on the facial feedback hypothesis raises the intriguing possibility that frowning may play a causal role in perception of effort and that an athlete could reduce their perception of effort during endurance performance by not frowning. Although the facial feedback hypothesis is mostly applied to emotional experience, research demonstrates that facial expressions can modulate what Stepper and Strack (1993) termed *non-emotional feelings*, such as perceived effort (Stepper & Strack, 1993, Study 2) and pain (Lanzetta, Cartwright-Smith, & Kleck, 1976, Experiment 1). In one of few studies that has applied research on the facial feedback hypothesis to sport and exercise, Philippen, Bakker, Oudejans, and Canal-Bruland (2012) found that exercisers reported greater pleasure and lower perception of effort when smiling compared to frowning, both at rest and during moderate-intensity cycling. This finding indicates that frowning, smiling, or both influenced the pleasure and perceived effort experienced by participants in this study. This study, however, did not include a no-intervention control condition to determine which facial expression caused the effects, which limits the conclusions that can be drawn from the findings. In order to determine whether interventions that are informed by the facial feedback hypothesis and that aim to reduce frowning could be used to enhance endurance performance, Chapter 4 examined whether frowning modulates perception of effort during endurance performance.

Psychological Factors That Affect Endurance Performance

The main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance. Research to date has examined the effects of a range of psychological interventions on endurance performance, as well as additional, relevant variables such as perception of effort. In this section, the effects of contextual variables, accurate and deceptive performance feedback, music, attentional focus, PST, and hypnosis are overviewed.

Contextual Variables

The characteristics of experimenters, observers, and coactors affect perception of effort and endurance performance. The presence of a female experimenter during heavy-workload cycling (Boutcher, Fleischer-Curtian, & Gines, 1988), the introduction of an attractive female observer during moderate-intensity running (Winchester et al., 2012), the presence of a male coactor during low- and moderate-intensity cycling (Hardy, Hall, & Prestholdt, 1986, Experiment 1), and specific social cues exhibited by a male coactor during moderate-intensity cycling (Hardy et al., 1986, Experiment 2) decreased male exercisers' ratings of perceived exertion. Additionally, the introduction of a male observer increased male exercisers' ratings of perceived exertion during moderate-intensity running (Winchester et al., 2012). These effects were not observed in females (Boutcher et al., 1988), and they were intensity-dependent (Boutcher et al., 1988; Hardy et al., 1986, Experiment 1). Furthermore, the race of the tester and whether the tester and participant are friends have also been shown to affect ratings of perceived exertion (Bubb et al., 1985). It is unclear, however, whether each of these contextual variables affected participants' actual perceptions of effort or, alternatively, the truthfulness of their self-reports.

With consideration to endurance performance, white females performed for longer during an incremental treadmill test when they were tested by a female (independent of the race of the tester), and black females performed for longer when they were tested by a male (Bubb et al., 1985, Study 1). Endurance performance, however, was not affected by participants being friends with the tester (Bubb et al., 1985, Study 2). Additionally, in a study of hospital patients, males reached higher power stages in incremental cycling tests (approximately 12% higher) when they were supervised by a female doctor compared to a male doctor (Jung, Ferrari, Goebel, & Figulla, 2009). They were also more likely to reach 90% of their predicted maximal heart rate, and they complained less frequently about chest pains during the test. Similar observations were not found for female patients. The mechanisms for these performance effects are unclear. Bubb and colleagues (1985) suggested that socialisation may have led some participants to believe that society expects them to not perform as well as other people, which could have increased their performance motivation or, alternatively, caused them to perform in a submissive manner, depending on the race and sex of the person conducting their exercise test. Jung and colleagues (2009) suggested that the presence of a female might have increased the motivation of male patients, who may have tried to impress the female testers using physical strength and by hiding physical discomfort or pain.

Presence and Accuracy of Performance Feedback

The presence of performance feedback influences endurance performance. For example, adult males ran for longer in two types of shuttle-run test (“beep tests”) when there was a verbal cue of the stage number (Metsios, Flouris, Koutedakis, & Theodorakis, 2006). Provision of performance feedback appears to be beneficial because of its effect on spontaneous goal setting (Lorimer & Babraj, 2013; Wilkinson, Fallowfield, & Myers, 1999). Indeed, Lorimer and Babraj (2013) demonstrated that 45% of recreationally-active males terminated an incremental cycling test within 10 seconds of reaching a new level of resistance, and none stopped during the final 10 seconds of a resistance stage. Qualitative data indicated that most participants felt that they could have continued cycling for longer, which suggests that the reason participants stopped at the beginning of a new level was not inability to cycle at the higher resistance. In addition, qualitative data indicated that participants used the feedback available to them (i.e., regular resistance increments) to spontaneously set themselves performance goals (i.e., reaching the next stage) that motivated them to persevere when they were close to exhaustion. Nevertheless, when participants reached a new stage but did not think that they could reach the next stage, they stopped almost immediately. Similarly, a disproportionate number of elite netball and lacrosse athletes terminated a shuttle-run test at the beginning of a new level, when new levels were indicated by a verbal cue and accompanied by a sudden increase in running speed

(Wilkinson et al., 1999). Depending on the perspective taken, spontaneous goal setting could be seen to enhance (i.e., by encouraging participants to persevere to the next stage) or undermine endurance performance (i.e., when participants terminate at the beginning of a stage despite being able to continue) (Lorimer & Babraj, 2013). Nevertheless, having the opportunity to set a performance goal for an upcoming incremental test and then receiving feedback on the lapsed performance time has been shown to increase performance time, compared to cycling without setting a goal or receiving feedback on the lapsed time (Theodorakis, Laparidis, & Kioumourtzoglou, 1998). This suggests that having the opportunity to use feedback to set a performance goal is generally beneficial for optimising endurance performance.

The accuracy of performance feedback also influences endurance performance, although the research findings are inconsistent. For example, competitive cyclists performed a 4-km velodrome time trial approximately 2.5% faster when a coach provided accurate, compared to non-contingent, visual feedback on whether they were performing faster or slower than their baseline performance (Mauger, Jones, & Williams, 2011). Other studies, however, suggest that the accuracy of feedback during performance does not affect time-trial performance (e.g., Albertus et al., 2005; Faulkner, Arnold, & Eston, 2011). Furthermore, some studies suggest that inaccurate feedback can enhance endurance performance if it makes the task more challenging. Indeed, trained male cyclists improved their 4-km time-trial performance by 1% when they raced against a computer-generated avatar representing their baseline performance (i.e., accurate performance feedback), and they improved their time by an additional 0.7% when the power output of the avatar was deceptively increased by 2% (Stone et al., 2012). Male participants, but not females, similarly increased their cycling time to exhaustion by nearly 28% when the calibration of a visible clock was deceptively adjusted to run 10% slower (Morton, 2009). This finding, however, was not replicated in 10-km cycling time trials (G. Thomas & Renfree, 2010). Insufficient psychological mediating variables were measured, however, to clarify why deceptive feedback had inconsistent effects in these studies.

Studies examining the effects of inaccurate feedback on endurance performance are considered part of a broader body of research examining the effects of various forms of deception (delivered before or during performance) on pacing, perceptual variables such as perception of effort, and endurance performance (H. S. Jones et al., 2013). Recently, H. S. Jones and colleagues (2013) argued that research examining the effects of participant deception has been more useful for understanding how athletes set and adjust their pacing strategy than for developing feasible methods of performance enhancement. They suggested that future research on deception should include psychological mediating variables—preferably using trained athletes in ecologically-valid settings—to clarify the deception-performance mechanism and to determine how deception could be used to enhance performance.

In summary, endurance performance is affected by the presence and accuracy of performance feedback provided during performance. Although research findings are inconsistent, providing feedback that is either accurate or adjusted to make the task slightly more challenging can have a beneficial effect on endurance performance. Psychological mediating variables should be measured in future research to clarify the intervention-performance mechanism and to inform feasible methods of performance enhancement.

Music

Listening to music before (A. Miller & Donohue, 2003; Smirmaul, dos Santos, & da Silva Neto, 2015) or during performance (e.g., Terry, Karageorghis, Saha, & D'Auria, 2012) can have a beneficial effect on endurance performance. Before performance, athletes can listen to music to support their mental preparation. For example, athletes in various sports listen to music to psych themselves up, to relax, to achieve an appropriate mental focus, or to increase their confidence (e.g., Bishop, Karageorghis, & Loizou, 2007; Smirmaul et al., 2015; Stanley et al., 2012). Indeed, it is common to see swimmers wearing headphones soon before they compete at events like the Olympics or the Commonwealth Games. Listening to music during performance can also be beneficial. Performers can listen to music during exercise to enhance their motivation (e.g., Barwood, Weston, Thelwell, & Page, 2009), as a method of distraction (e.g., L. M. Scott, Scott, Bedic, & Dowd, 1999), and to enhance their performance (e.g., Terry, Karageorghis, Saha, & D'Auria, 2012).

A substantial amount of research supports the efficacy of music as an ergogenic aid for exercise, including endurance exercise (for reviews, see Karageorghis & Priest, 2012a, 2012b; Karageorghis & Terry, 1997). In the first review of this research area, Karageorghis and Terry (1997) concluded that hearing synchronous music during exercise was consistently associated with increased work output. Much of the research published since this review, however, has examined the effects of hearing asynchronous music during exercise (Karageorghis & Priest, 2012a, 2012b). Music has consistently shown performance-enhancing effects in low, moderate, and high-intensity exercise tasks. Additionally, music is associated with positive affective states during exercise at all intensities, as well as reduced perception of effort during endurance exercise below the lactate threshold. Furthermore, music appears to have a greater effect when it is specifically chosen for its motivational qualities, when participants are untrained or recreationally active, and in studies that possess high ecological validity, such as studies that allow athletes to self-pace or to select the music they listen to (Karageorghis & Priest, 2012a, 2012b). With consideration for endurance performance specifically, music has been shown to endurance performance in running (Terry et al., 2012), cycling (Atkinson, Wilson, & Eubank, 2004), rowing (Rendi, Szabo, & Szabó, 2008), and swimming tasks (Tate, Gennings, Hoffman, Strittmatter, & Retchin, 2012). Facilitative music for endurance performance has included trance (Atkinson et al., 2004), classical (Rendi et al., 2008), self-chosen tracks (Tate et al., 2012), easy-listening popular music (Copeland & Franks, 1991), and motivational or motivationally-neutral popular music (Terry et al., 2012). The benefits of listening to music during exercise have been attributed to the music's effect on attentional focus, its stimulative or sedative properties, its emotional impact, and induced synchronisation between the exerciser's movements and the musical rhythm (Karageorghis & Priest 2012a; Karageorghis & Terry, 1997).

Associative and Dissociative Cognitive Strategies

Endurance exercisers can listen to music to distract themselves from exercise sensations such as perception of effort and pain (Rejeski, 1985). Distraction could be a valuable attentional strategy if the exerciser's goal is to complete a set amount of exercise, such as a certain distance during a training run. Distraction is undesirable, however, when a performer needs to pay attention to technique or pacing-related cues (e.g., exercise sensations and other competitors). A substantial volume of research has examined the effects of different attentional strategies, dating back to Morgan and Pollock's (1977) distinction between associative and dissociative cognitive strategies. Morgan and Pollock reported that elite marathon runners tended to use an *associative* cognitive strategy; they monitored their bodily sensations (e.g., breathing, feelings of pain or fatigue), and they used these sensations as feedback to regulate their pace. Morgan and Pollock contrasted associative cognitive strategies with *dissociative* strategies, whereby exercisers direct their attention elsewhere (e.g., distractive thoughts, scenery) to reduce uncomfortable exercise sensations. Masters and Ogles (1998) reviewed the first twenty years of research on associative and dissociative strategies, and they concluded that association is generally associated with faster running times, faster running pace, and running performances in competition. Dissociation, on the other hand, is associated with running performances in training, improved muscular endurance performance, less physiological awareness, and reduced perception of effort.

More recently, Lind, Welch, and Ekkekakis (2009) argued that research on attention during exercise should recognise that the effects of attentional focus are dependent on exercise intensity. These authors argued that dissociative strategies reduce perception of effort and enhance affective responses to exercise (i.e., they lead to exercise feeling more pleasurable) at low and moderate exercise intensities, but these strategies are less efficacious at higher intensities and near exhaustion when physiological cues such as muscle pain and heavy breathing dominate attentional focus. Theoretical perspectives of perception of effort (Noble & Robertson, 1996b; Rejeski, 1985; Tenenbaum, 2001) similarly suggest that exercisers can dissociate during low-intensity exercise when attention is more flexible, but cognitions become increasingly focused on bodily sensations as a consequence of increases in exercise workload or duration. Indeed, reported cognitions become more associative with an increase in duration or workload (Hutchinson & Tenenbaum, 2007; Tenenbaum & Connolly, 2008), and task-unrelated thoughts become more difficult to sustain as an exerciser approaches exhaustion (Balagué et al., 2015).

Morgan and Pollock’s (1977) distinction between associative and dissociative cognitive strategies, as well as the subsequent research reviewed by Masters and Ogles (1998), suggested that an exerciser’s focus of attention could be classified into one of two broad categories. More recent theoretical perspectives, however, argue that attentional strategies should be categorised more precisely (Brick et al., 2014; Stevinson & Biddle, 1998, 1999). Following ambiguity and inconsistency in the use of the terms association and dissociation, Stevinson and Biddle (1998, 1999) proposed a two-dimension classification system for describing associative and dissociative thoughts (for a summary, see Table 3, p. 43). Within this classification system, a *task relevance* dimension distinguishes (task-relevant) associative thoughts and (task-irrelevant) dissociative thoughts. Additionally, associative and dissociative thoughts can be further classified through a second *direction of attention* dimension; thoughts can be classified as having an internal or external direction of attention. More recently, however, Brick and colleagues (2014) expanded Stevinson and Biddle's classification system to a five-category model (for a summary, see Table 4, p. 44). This newer model explains inconsistencies in research findings and better accommodates thoughts relating to technique, which do not fit clearly within Stevinson and Biddle's classification system. Specifically, Brick and colleagues (2014) expanded the internal, associative dimension of Stevinson and Biddle's (1998, 1999) classification system to distinguish between *internal sensory monitoring* and *active self-regulation*. Whereas internal sensory monitoring involves paying attention to bodily sensations (e.g., breathing, muscle soreness), active self-regulation reflects efforts to control or monitor thoughts, feelings, or actions. Self-regulatory cognitions include focusing on technique, cadence, pacing, or relaxing, and they may enhance endurance performance by optimising pace or by improving movement efficiency. Research suggests that, unlike internal sensory monitoring, increasing pace by active self-regulation does not necessarily elevate perception of effort (e.g., Couture, Jerome, & Tihanyi, 1999). In addition, Brick and colleagues (2014) argued that the distinction between internal and external dissociation explains few differences in performance or perception of effort, and they suggested that a distinction between *active distraction* and *involuntary distraction* is more useful for explaining the effects of distractive cognitions. In other words, dissociative cognitions could be distinguished by whether they are intentional or unintentional.

Overall, endurance performance is affected by a performer's focus of attention throughout the performance. Task-irrelevant, dissociative thoughts reduce perception of effort during exercise at lower exercise intensities (Lind et al., 2009), but task-irrelevant thoughts are difficult to sustain at high exercise intensities and when approaching exhaustion (e.g., Balagué et al., 2014). Task-irrelevant thoughts might also undermine an athlete's execution of optimal movement technique or their ability to pace themselves effectively during competition. Dissociative cognitive strategies could therefore be useful during long training runs or non-competitive, long-distance events (e.g., some ultramarathons), when the goal is to complete the distance rather than to achieve an optimal performance time. Associative cognitive strategies, in contrast, could be used in competitive events to optimise pace or movement efficiency and to monitor performance-related external cues, such as the route and other competitors (Brick et al., 2014). Indeed, observational and correlational studies suggest that higher-level endurance athletes typically demonstrate associative cognitions during competition (Masters & Ogles, 1998). There are relatively few experimental studies, however, that have examined the efficacy of intentionally using associative and dissociative strategies to enhance endurance performance. These studies are examined in the systematic review reported in Chapter 2.

Table 3

Stevinson and Biddle's (1998, 1999) Thought Classification System (With Examples)

		Task relevance dimension	
		Task-relevant (association)	Task-irrelevant (dissociation)
Direction of attention dimension	Internal	*Inward monitoring* Focusing on breathing, muscle soreness, fatigue, perspiration, thirst, and blisters.	*Internal dissociation* Focusing on irrelevant daydreams, imagined music, maths puzzles, and reflective thoughts.
	External	*Outward monitoring* Focusing on strategy, split times, the route, mile markers, conditions, and water stations.	*External dissociation* Focusing on unimportant scenery, spectators, and other performers.

Table 4

Brick, MacIntyre, and Campbell's (2014) Thought Classification System (With Examples)

Re-categorisation of traditional associative cognitions	Re-categorisation of traditional dissociative cognitions
Internal sensory monitoring	*Active distraction*
Focusing on breathing, muscle soreness, fatigue, perspiration, thirst, and blisters.	Focusing on attention-demanding tasks (e.g., puzzles), attention-demanding environmental conditions (e.g., urban street), conversing, and other intentional distractions.
Active self-regulation	*Involuntary distraction*
Focusing internally on technique, cadence, maintaining a relaxed state, pacing, and strategy.	Focusing on unimportant scenery, attractive environments, spectators, other non-competitive runners, reflective thoughts, irrelevant daydreams, and imagined music.
Outward monitoring	
Focusing on other competitors, split times, the route, mile markers, conditions, and water stations.	

Psychological Skills Training

Sport psychology researchers and practitioners have taught psychological skills to improve athletic performance and quality of participation in a wide range of sports. These PST interventions often include goal setting, self-talk, imagery, and relaxation strategies, individually or in combination. For example, Bull (1989) provided psychological support to an ultra-distance runner before and during a 19-day desert run, and he encouraged the runner to use various strategies that included association, goal setting, imagery, relaxation, and self-talk. Similarly, PST was included in the psychological support provided to a person who successfully walked the same mile 1,000 times during 1,000 consecutive hours (Breslin, Murphy, Kremer, McClean, & Davison, 2014). Meta-analyses support the efficacy of goal setting (Kyllo & Landers, 1995), imagery (Curran, 2008), self-talk (Hatzigeorgiadis, Zourbanos, Galanis, & Theodorakis, 2011), and PST packages (Hatzigeorgiadis et al., 2011) for enhancing performance in a wide range of sport and exercise tasks. Studies have also shown that PST can enhance performance in continuous and gross-skill sports, such as running (Mallett & Hanrahan, 1997), swimming (Hatzigeorgiadis, Galanis, Zourbanos, & Theodorakis, 2014), and speed skating (Wanlin, Hrycaiko, Martin, & Mahon, 1997). Studies that have examined the effects of PST on endurance performance will be reviewed thoroughly in Chapter 2.

There are various mechanisms through which PST could enhance endurance performance. For example, setting a goal such as a performance time, competitive outcome, or completing a long-distance event could be beneficial if it enhances effort in training (Wanlin et al., 1997), if it encourages persistence during the event, or if the athlete learns new skills (e.g., improves their running form) in order to achieve the goal (Locke & Latham, 2002). In addition, self-talk could be used to enhance attentional focus on task-related cues during training (e.g., technique) or competition (e.g., route markers, other competitors), to maintain a high level of effort in training and competition, or to cope with stressors and associated emotions (Theodorakis, Hatzigeorgiadis, & Chroni, 2008). Further, imagery could be used to encourage a challenge response to upcoming competition (S. E. Williams, Cumming, & Balanos, 2010), and relaxation skills could have a beneficial effect on the running economy of long-distance runners (Caird, McKenzie, & Sleivert, 1999).

Sport psychology practitioners designing a PST intervention should consider the needs of the individual athlete (determined through an assessment) and the demands of the sport (Taylor, 1995). The demands of the sport are divided into physical demands (e.g., explosiveness versus endurance), technical demands (e.g., fine motor and gross motor), logistical demands (e.g., duration of performance, pre-performance preparation requirements), and psychological demands. Tuffey (2000) proposed that endurance athletes experience three broad psychological demands: 1) long and repetitive training sessions that can undermine motivation; 2) pain, discomfort, and fatigue experienced in training and competition; and 3) preparation for competition, including planning for pain and discomfort and developing and committing to a race plan. These psychological demands, however, are supported by practitioner experience and anecdotal evidence rather than a body of relevant research. In fact, few studies have identified psychological demands experienced by endurance athletes, particularly demands that are common across different endurance sports. Chapter 3 of this thesis aims to identify psychological demands that are commonly experienced by endurance athletes who compete in various endurance sports, competitive distances, and competitive levels, in order to inform the design of a performance-enhancement psychological intervention.

Hypnosis

Psychological theoretical perspectives of perception of effort (Noble & Robertson, 1996b; Rejeski, 1985) suggest that hypnosis interventions can influence perception of effort pre-consciously by amplifying or dampening exercise-related sensory cues. Indeed, post-hypnotic suggestions of lighter and heavier work (Morgan, Hirta, Weitz, & Balke, 1976) and downhill and uphill cycling grade (Williamson et al., 2001) have been used to manipulate perception of effort during ergometer exercise. If hypnosis can reduce perception of effort, then it could potentially be used to enhance endurance performance. Few studies, however, have examined the effects of hypnosis on endurance performance. Specifically, listening to a motivational passage following hypnosis enhanced performance in an incremental running test for males who were highly susceptible to hypnosis, although it did not enhance performance for males who were low in susceptibility (Jackson, Gass, & Camp, 1979). It is unclear whether hypnosis-based interventions offer a feasible method of performance enhancement for practitioners working with endurance athletes. Nevertheless, a study that used a single-subject, multiple-baseline design offered some preliminary support. Specifically, a hypnosis intervention that was delivered by a sport psychology practitioner trained in hypnotic techniques led to two of three cyclists winning more points in competitive road races (Lindsay, Maynard, & Thomas, 2005). This hypnosis intervention was used to condition natural triggers experienced during races (e.g., feel of handlebars) to emotions associated with optimal performance.

Chapter Summary

For the purpose of this thesis, endurance performance is defined as performance during whole-body, dynamic exercise that involves continuous effort and lasts for 75 seconds or longer. Running, cycling, swimming, triathlon, rowing, and speed-skating events are among the events that are consistent with this definition of endurance performance. This definition recognises that pacing is a characteristic of endurance performance, it recognises the substantial contribution of the aerobic energy system during endurance performance, and it provides an objective eligibility criterion for the systematic literature review reported in Chapter 2. Researchers frequently use time trials and time-to-exhaustion tests to measure endurance performance, and the choice of performance measure should depend on the aims of the research. Time-to-exhaustion tests are useful for examining an intervention-performance mechanism because the participant performs at a fixed workload. Indeed, Chapter 4 uses a time-to-exhaustion test to determine whether frowning modulates perception of effort and, as a consequence, influences endurance performance. Time trials, on the other hand, are useful for examining the effects of an intervention for athletes (e.g., time-trial cyclists) who self-pace during competition (Amann et al., 2008; Currell & Jeukendrup, 2008).

Next, this chapter overviewed contemporary theoretical perspectives that offer different explanations of how endurance performance is determined. These theoretical perspectives are mostly grounded in exercise physiology, and most suggest that physiological variables or physiological processes are the main determinants of endurance performance. Across the theories, there appears to be agreement that an athlete’s physiology determines the upper limit of their performance potential, and psychological factors could influence how close an athlete performs to their potential. The psychobiological model of endurance performance is particularly relevant to this thesis, as it proposes that psychological constructs play key roles in determining endurance performance and it specifies how they do so. Although physiological factors influence endurance performance through their effects on perception of effort, this theory suggests that endurance athletes ultimately make conscious decisions to regulate pace and terminate performance based on their perception of effort and potential motivation. Chapter 2 (systematic literature review) examines whether there is experimental support for the predictions of the psychobiological model that psychological interventions affect endurance performance by influencing either perception of effort or potential motivation. Three psychological theories that informed the studies conducted within the thesis (CMR theory, the Theory of Challenge and Threat States in Athletes, and the facial feedback hypothesis) were also overviewed. Although these theories do not explicitly explain how endurance performance is determined, they explain sport performance and can be applied to endurance sports. Finally, this chapter overviewed psychological factors that affect endurance performance. These psychological factors were contextual variables, accurate and deceptive performance feedback, music, associative and dissociative cognitive strategies, PST, and hypnosis. Experimental research examining the effects of psychological interventions on endurance performance will be scrutinised in Chapter 2.

Aims and Overview of Thesis

With an emphasis on endurance sports, the main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance. By doing so, this thesis has the potential to inform evidence-based application of psychology in endurance sports. There were three main research aims. First, this thesis aimed to synthesise research conducted to date on the psychological determinants of endurance performance. Second, this thesis aimed to inform the design of performance-enhancement psychological interventions for endurance sports. Third, this thesis aimed to examine the effect of a PST intervention on performance in a real-life endurance event. Four studies were conducted to achieve these aims.

The first aim of the thesis (to synthesise research on the psychological determinants of endurance performance) was addressed in Chapter 2 using a systematic literature review. Systematic reviews aim to identify and synthesise all studies that are relevant to a particular research question, whilst appraising the quality of each study to limit bias. In doing so, systematic reviews can identify gaps in the literature, direct future research, and support evidence-based decision making by identifying interventions that have been shown to be effective by reliable studies (Petticrew &

Roberts, 2006). The systematic review reported in Chapter 2 aimed to identify practical psychological interventions that enhance endurance performance and to identify additional psychological determinants of endurance performance. Additional objectives of the systematic review were to evaluate the research practices of included studies, to suggest theoretical and applied implications, and to guide future research.

The second aim of this thesis (to inform the design of performance-enhancement psychological interventions for endurance sports) was addressed through two studies. Chapter 3 describes a qualitative study that aimed to increase understanding of psychological demands that are commonly experienced by endurance athletes. Interventions that help endurance athletes to cope with psychological demands commonly experienced before or during endurance events could potentially enhance performance in endurance events. Focus group interviews were conducted with 30 recreational endurance athletes of various sports (running, cycling, and triathlon), distances, and competitive levels to explore psychological demands of training, competition preparation, and competition participation, and to identify psychological demands that were experienced across sports, distances, and competitive levels.

Chapter 4 also addressed the second aim of the thesis, which was to inform the design of performance-enhancement psychological interventions for endurance sports. Chapter 2 (systematic literature review) highlighted a paucity of theoretically-informed research on the psychological determinants of endurance performance. Chapter 4 applied psychological theory to examine a novel method of influencing endurance performance. Although people frown more when they perceive high levels of effort, research on the facial feedback hypothesis suggests that frowning might also modulate (amplify or soften) perception of effort. In other words, frowning (or not frowning) could influence how strenuous endurance exercise feels to an athlete. If frowning does modulate perception of effort, then interventions aimed at reducing frowning could offer a novel, psychologically-informed method of enhancing endurance performance. Applying predictions of the facial feedback hypothesis and the psychobiological model of endurance performance, Chapter 4 investigated whether intentionally frowning throughout a cycling time-to-exhaustion test increased perception of effort and reduced cycling time to exhaustion. Ten recreational endurance athletes performed cycling time-to-exhaustion tests in three conditions that were completed in a randomised and counterbalanced order. In a frowning condition, participants frowned throughout the time-to-exhaustion test. In a matched-workload control condition, participants pressed their thumb against the ergometer handlebar throughout the time-to-exhaustion test. Electromyography root mean square feedback was used to deliver these interventions. There was also a no-intervention control condition. Perception of effort and cycling time to exhaustion were the main dependent variables.

The third aim of this thesis was to examine the effect of a PST intervention on performance in a real-life endurance event. Chapter 2 found that a considerable amount of research demonstrates that psychological interventions such as PST enhance endurance performance in non-competitive, laboratory and field-based endurance tasks. Few studies, however, have examined the effects of psychological interventions on performance in real-life endurance events, particularly using randomised, controlled experiments. Chapter 5 examined the effect of a motivational self-talk intervention on performance in an ultramarathon. It applied research evidence of efficacious psychological interventions for endurance sports (Chapter 2) to target psychological demands experienced by endurance athletes (Chapter 3). Specifically, 21 participants in a 60-mile, overnight ultramarathon were matched by their estimated $\dot{V}O_{2max}$ and randomly allocated to a motivational self-talk group or a control group. Participants in the self-talk group used a workbook to identify motivational self-talk statements to use during the beginning, middle, and later stages of the ultramarathon, to counter thoughts about withdrawing effort, and in response to adversity (e.g., getting lost, falling behind targets). Self-talk was chosen because research that was at lower risk of bias demonstrated that it is efficacious in controlled conditions (Chapter 2). Participants in the control group used concentration grids to develop their concentration. Performance time was the main dependent variable. In addition, Chapter 5 examined whether learning to use motivational self-talk increased pre-event self-efficacy and perceived control, which influence challenge responses to upcoming competition, and it examined whether participants continued to use self-talk after their commitment to the study.

Thesis Format

The remainder of the thesis consists of one systematic literature review, one qualitative study, one psychophysiology experiment in laboratory settings, one experiment in field settings, and one qualitative discussion of the findings. I was the principle researcher for the research chapters (systematic review, qualitative study, psychophysiology experiment, and field experiment). Additional researchers are acknowledged on the title page for each research chapter. The four research chapters are written as stand-alone papers. To facilitate reading, however, tables and figures are numbered consecutively, and a single reference list is presented at the end of the thesis. Abbreviations are also defined at their first appearance within each chapter. All manuscripts were written following the guidelines of the sixth edition of the Publication Manual of the American Psychological Association (2009). As an exception, means and standard deviations are presented as mean ± standard deviation (e.g., 7 ± 2) to facilitate reading, because they are frequently reported.

Chapter 2

Psychological Determinants of Endurance Performance: A Systematic Review

Alister McCormick, Carla Meijen, and Samuele Marcora

Endurance Research Group, School of Sport & Exercise Sciences, University of Kent, Medway Building, Chatham Maritime, Kent, ME4 4AG, United Kingdom

This chapter has been published in *Sports Medicine*:

McCormick, A., Meijen, C., & Marcora, S. (2015). Psychological determinants of whole-body endurance performance. *Sports Medicine*, *45*, 997-1015. doi:10.1007/s40279-015-0319-6

Aim of Chapter 2

The main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance. The thesis had three main research aims: 1) to synthesise research conducted to date on the psychological determinants of endurance performance; 2) to inform the design of performance-enhancement psychological interventions for endurance sports; and 3) to examine the effect of a psychological skills training intervention on performance in a real-life endurance event. Chapter 2 used a systematic literature review to address the first research aim of the thesis. Systematic reviews are useful for identifying gaps in the literature and directing future research, including the research reported within this thesis. For example, the systematic review highlighted that no published studies have examined the effect of psychological skills training on performance in a real-life endurance event using a randomised, controlled experiment. Chapter 5 used a randomised, controlled experiment to examine the effect of motivational self-talk on performance in an ultramarathon. Systematic reviews are also useful for informing evidence-based practice (Petticrew & Roberts, 2006) and could therefore provide an evidence base for using psychology to enhance endurance performance in applied contexts.

Abstract

Background: No literature reviews have systematically identified and evaluated research on the psychological determinants of endurance performance, and sport psychology performance-enhancement guidelines for endurance sports are not founded on a systematic evaluation of endurance-specific research. ***Objectives:*** A systematic literature review was conducted to identify practical psychological interventions that enhance endurance performance and to identify additional psychological determinants of endurance performance. Additional objectives were to evaluate the research practices of included studies, to suggest theoretical and applied implications, and to guide future research. ***Methods:*** Electronic databases, forward-citation searches, and manual searches of reference lists were used to locate relevant studies. Peer-reviewed studies were included when they chose an experimental or quasi-experimental research design, a psychological independent variable, endurance performance as the dependent variable, and athletes or physically-active, healthy adults as participants. ***Results:*** Consistent support was found for using imagery, self-talk, and goal setting to enhance endurance performance, but it is unclear whether learning multiple psychological skills is more beneficial than learning one psychological skill. The results also demonstrated that mental fatigue undermines endurance performance, and verbal encouragement and head-to-head competition can have a beneficial effect. Interventions that affected perception of effort consistently affected endurance performance. ***Conclusions:*** Psychological skills training could benefit an endurance athlete. Researchers are encouraged to compare different practical psychological interventions, to examine the effects of these interventions for athletes in competition, and to include a placebo control condition or an alternative control treatment. Researchers are also encouraged to explore additional psychological factors that could have a negative effect on endurance performance. Future research should include psychological mediating variables and

moderating variables. Implications for theoretical explanations of endurance performance and evidence-based practice are described.

Introduction

A systematic literature review was conducted to identify practical psychological interventions that enhance endurance performance and to identify additional psychological determinants of endurance performance. For the purpose of this review, endurance performance is defined as performance during whole-body, dynamic exercise that involves continuous effort and lasts for 75 seconds or longer (see next paragraph). Although single or combined running, cycling, and swimming events (e.g., marathons, triathlons, ultramarathons) are most often associated with endurance, other endurance sports could include rowing, canoeing, cross-country skiing, and speed skating. Visual inspection of the performance times at the London 2012 Summer Olympics (www.olympic.org/sports) suggested that more than 70 events met our definition of endurance performance. Endurance events are also popular with recreational participants. For example, approximately 57,000 people participated in the 2015 Great North Run half-marathon ("Great North Run: Farah wins as thousands take on half marathon," 2015). Identification of psychological interventions that have a causal relationship with endurance performance would support evidence-based sport psychology practice. At present, however, no literature reviews have systematically identified and evaluated research on psychological determinants of endurance performance. Furthermore, in sport psychology, performance-enhancement guidelines for endurance sports (Dosil, 2006; Kellmann, Bußmann, Anders, & Schulte, 2006; Simons, 2012; Taylor & Kress, 2006; Tuffey, 2000) are not founded on a systematic evaluation of endurance-specific research.

Sport psychology research on endurance performance can be divided into muscular endurance and aerobic endurance (Brick et al., 2014). This review focuses on aerobic endurance, because it represents those whole-body endurance tasks that people perform recreationally and competitively, such as running, cycling, swimming, and rowing. Physiologically, aerobic endurance relies primarily on energy that is derived from aerobic—as opposed to anaerobic—metabolism. The aerobic energy system produces large amounts of energy through combustion of carbohydrates and fats, but it produces energy at a slower rate than the anaerobic energy system (Gastin, 2001). The relative contribution of the aerobic energy system increases with the duration of maximum-effort exercise, and the relative contribution of the aerobic energy system generally predominates after approximately 75 seconds of maximum-effort exercise (Gastin, 2001). As an eligibility criterion, endurance performance was therefore defined as performance during whole-body, dynamic exercise that involves continuous effort and lasts for 75 seconds or longer.

This review focuses on the psychological determinants of endurance performance. Whereas a *correlate* demonstrates a reproducible association or predictive relationship with a dependent variable, a *determinant* demonstrates a cause-and-effect relationship (Bauman, Sallis, Dzewaltowski, & Owen, 2002). Correlates of endurance performance include positive affect (Renfree, West, Corbett, Rhoden, & St Clair Gibson, 2012), self-efficacy (J. J. Martin & Gill, 1991), use of psychological strategies (Houston, Dolan, & Martin, 2011), personal-standards perfectionism, performance-approach goals, and self-set personal goals (Stoeber, Uphill, & Hotham, 2009). This systematic review aimed to support evidence-based practice by identifying practical psychological interventions and other psychological interventions that have been shown to have a causal relationship with endurance performance in experimental or quasi-experimental research (i.e., psychological determinants).

Practical psychological interventions were defined as psychological interventions judged to be ethical, feasible, and accessible to a sport practitioner, coach, or athlete. Although meta-analyses support use of goal setting (Kyllo & Landers, 1995), imagery (Curran, 2008), self-talk (Hatzigeorgiadis et al., 2011), and psychological skills training (PST) packages (Hatzigeorgiadis et al., 2011) to enhance performance in a range of sport and exercise tasks, the effects of PST on endurance performance have not been reviewed. In contrast, associative and dissociative cognitive strategies have received much interest in the endurance literature (for reviews, see Brewer & Buman, 2006; Brick et al., 2014; Lind et al., 2009; Masters & Ogles, 1998; Salmon, Hanneman, & Harwood, 2010). Much research on association and dissociation, however, is correlational or observational (Masters & Ogles, 1998). This review is interested in the experimental studies that have examined whether these cognitive strategies affect endurance performance. Although music, placebos, feedback, and deception can be used to enhance endurance performance (see Chapter 1), they were not included in the present review, because these psychological interventions have been thoroughly and recently reviewed elsewhere (Beedie & Foad, 2009; Bérdi, Köteles, Szabó, & Bárdos, 2011; H. S. Jones et al., 2013; Karageorghis & Priest, 2012a, 2012b).

Identification of practical psychological interventions that enhance endurance performance, as well as additional psychological determinants of endurance performance, could benefit the performance of competitive endurance athletes. Further, identifying methods that enhance endurance performance could encourage recreational participants' continued involvement in endurance sports by increasing their self-efficacy (Desharnais, Bouillon, & Godin, 1986) or perceived competence (Ryan, Frederick, Lepes, Rubio, & Sheldon, 1997). Although experimental and quasi-experimental studies have been examining the effects of psychological interventions on endurance performance for nearly 50 years (Wilmore, 1968), the psychological determinants of endurance performance have not been reviewed systematically. A systematic literature review was therefore conducted to identify the psychological interventions that have been shown to affect (or not affect) endurance performance and to evaluate the research practices of these studies. By synthesising research on the psychological determinants of endurance performance, this systematic review aimed to inform theoretical perspectives of endurance performance, support evidence-based practice, and guide future research.

Methods

Sources

Studies were identified by searching the following resources: (a) electronic databases (Academic Search Complete, PsycARTICLES, PsycINFO, Scopus, and Web of Knowledge); (b) reference lists of included studies and other psychological research articles, review articles, and book chapters on endurance performance and related topics (e.g., perception of effort, association and dissociation); and (c) forward-citation results in Google Scholar and Web of Knowledge. Academic Search Complete, PsycARTICLES, and PsycINFO were searched together using EBSCOhost. In total, 128 endurance-related keyword variations were included in database searches (Appendix A, p. 253). All available publication years were searched up to December 2014. Depending on the database search options, keywords were searched in both article titles and abstracts. Because "endurance" is relevant to many sports and experimental procedures, 12 separate database searches were conducted for keywords relating to the following: endurance performance and its measurement (e.g., time-to-exhaustion), physiological dependent variables that may be measured during endurance performance (e.g., economy, pacing, $\dot{V}O_{2max}$), running (e.g., cross-country, marathon), cycling (e.g., ergometer), rowing (row OR rower OR rowers OR rowing), skiing, canoeing, kayaking, swimming, speed skating, triathlon, and race walking. Keywords were separated by the OR operator. Results were narrowed using the AND operator, which was combined with 78 keywords related to psychological states (e.g., anxiety), cognitive and behavioural strategies (e.g., self-talk), and other psychological interventions (e.g., reward). In Scopus and Web of Knowledge, the results were narrowed by filtering relevant research areas and subject areas, respectively (e.g., physiology, psychology, sport sciences). If an individual search returned over 1,000 results in EBSCOhost, the results were narrowed by filtering articles that included the words “sport”, “exercise”, or “perform*” in the whole text. Abstracts of returned articles were examined unless the article’s title was clearly inconsistent with the topic of this review. The full text was examined if the abstract indicated that the study might meet the eligibility criteria, if the abstract provided insufficient information, or if the abstract was unavailable.

Eligibility Criteria

Studies were included if they met the following criteria: (a) written in English language; (b) published in a peer-reviewed journal; (c) used an experimental or quasi-experimental research design; (d) chose athletes or physically-active, healthy adults as participants; (e) used a psychological independent variable; (f) met our definition of endurance performance; and (g) measured performance time, distance covered, work completed, total power output, peak power output, peak velocity, or competitive outcome as the dependent variable. When studies did not quote performance times, 200 metres was classed as the shortest endurance distance in swimming, and 800 metres was classed as the shortest endurance distance in running; maximum-effort performances at and above these distances would last longer than 75 seconds and therefore satisfied our definition of endurance performance. As this review is interested in endurance *performance*, studies were excluded if participants were asked not to offer their maximum effort in the endurance task. To support evidence-based practice, studies that compared practical psychological interventions without a within- or between-subjects control were excluded, because it was not possible to judge whether any intervention was beneficial compared to no intervention. Feedback, deception, music, and placebos were not included, because these psychological interventions have been reviewed previously.

Evaluation of Study Quality

All included studies were evaluated using a modified version of the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (B. H. Thomas, Ciliska, Dobbins, & Micucci, 2004). The application instructions were modified to increase the relevance of the tool to sport science research (see Appendix B, p. 255, for the modified application instructions). Studies were assigned "weak", "moderate", or "strong" ratings for the following components when they were judged to be applicable: study design, confounders, blinding, data collection methods, and withdrawals and dropouts. Judgments were made when the "correct" rating was unclear. When studies were assigned no "weak" ratings, they were assigned an overall rating of either "strong" (50% < "strong" ratings) or "moderate" (50% > "strong" ratings). Studies with one "weak" rating were assigned an overall rating of "moderate", and studies with two or more "weak" ratings were assigned an overall rating of "weak". Intervention integrity was also evaluated, but studies are not assigned a quality label for this component. The selection bias component of the tool was not applied, because it is common practice for sport science studies to recruit participants using advertising material and by approaching sport teams (studies would be assigned "weak" for self-referral). Participants in all but one of the studies (Donohue, Barnhart, Covassin, Carpin, & Korb, 2001) were self-referred, and including the selection bias component would therefore have reduced the discriminative ability of the tool. To safeguard against data extraction bias, an external researcher independently evaluated a random selection of nine studies (20%) using the modified tool (Petticrew & Roberts, 2006). The two researchers then critically discussed the application of the tool to each of these studies. The independent researcher agreed with the overall quality label assigned to all nine studies. An audit trail was also used to document the decision-making process for all included studies (see Appendix C, p. 258, for an example).

Additional evaluation criteria were also applied. Moderating variables, psychological mediating variables, and the number of participants whose endurance performance changed were recorded when applicable (G. L. Martin, Vause, & Schwartzman, 2005). The presence of the following study characteristics were recorded for studies examining practical psychological interventions: a placebo control condition; an intervention-adherence check when use of an intervention was not observable (e.g., cognitive strategy, intervention practised at home); a description of the qualifications or experiences of the person delivering the intervention; a social-validity or consumer-satisfaction measure (G. L. Martin et al., 2005); and the number of measured performances after intervention withdrawal (G. L. Martin et al., 2005).

Effect Sizes

Effect sizes were calculated when mean and standard deviation values were either reported in the manuscript or provided by the authors on request. Glass's delta (Δ) value was calculated for within-subject group designs (Hojat & Xu, 2004). For pretest-posttest designs with a control group, delta values were calculated using the formula recommended by Morris (2008). For these two designs, the most recent control trial was chosen to calculate the effect sizes. When group-design studies included two main endurance-performance dependent variables (e.g., performance duration and total power output, multiple performance distances), mean effect sizes (weighted by sample size) were calculated. For single-subject, multiple-baseline designs, effect sizes were calculated for each participant and then a weighted average (accounting for missed trials) was calculated for the intervention (Beeson & Robey, 2006). For three of these studies (Patrick & Hrycaiko, 1998; Thelwell & Greenlees, 2001, 2003), performance times were not stated and could not be determined precisely using manuscript graphs. Enlarged graphs were therefore printed, and the vertical distances of the data points from the *X* axis were measured by ruler. Effect sizes were then calculated by replacing performance times with the measured distances (Beeson & Robey, 2006). Small, moderate, and large effect-size anchors are substantially higher in single-subject designs (e.g., 2.6, 3.9, and 5.8, respectively, in a non-sport context, see Beeson & Robey, 2006) than in group designs (e.g., 0.2, 0.5, and 0.8, respectively, see Cohen, 1988). Readers should take these differences into account when comparing effect sizes. To avoid reporting misleading effect sizes for single-subject, multiple-baseline designs, the percentage of non-overlapping data points (PND) was also calculated for each participant in a single-subject, multiple-baseline design study, and mean PND scores are reported for each intervention. This percentage is the proportion of a participant's post-intervention performances that were better than their best pre-intervention performance. Scores of 90% suggest a very effective treatment, scores of 70-90% suggest an effective treatment, scores of 50-70% suggest questionable effectiveness, and scores below 50% suggest an ineffective treatment (Scruggs & Mastropieri, 2001). To calculate an overall effect size for an intervention, effect sizes from different studies were weighted by the respective sample size (effect sizes from group-design studies and single-subject, multiple-baseline studies were not combined).

Results

A search strategy with high sensitivity and low specificity was chosen to locate a high proportion of relevant studies (Petticrew & Roberts, 2006). This search strategy led to excessive database returns (>30,000 non-unique returns), and it was unfeasible to represent the search strategy in a flow chart. Nevertheless, the full texts of 101 studies were assessed for eligibility, and 46 studies were included (see Table A1, Appendix D, p. 262, for the reasons for exclusion). Studies that used practical psychological interventions (*n* = 25) are presented separately from the additional psychological determinants (*n* = 21). Table 5 (practical psychological interventions) and Table 6 (additional psychological determinants) present the information that was extracted from the included studies and evaluated, including the assigned quality ratings (pp. 91-92). Table A2 (practical psychological interventions) and Table A3 (additional psychological determinants) provide an overview of each included study (Appendix E, p. 267). A narrative synthesis of evidence was chosen because of the heterogeneity of the independent and dependent variables, study designs, and participant competitive levels (Petticrew & Roberts, 2006).

Quality of Included Studies

Two studies were assigned a "strong" rating for overall quality (4%), 31 studies were assigned "moderate" (69%), 12 studies were assigned "weak" (27%), and one study was assigned "not applicable". Eighteen studies (40%) were assigned a "strong" rating for their study design, 14 studies were assigned "moderate" (31%), and 13 studies were assigned "weak" (29%). Confounders were identified in four (9%) of the included studies; in these studies, data were collected at different races (Lindsay et al., 2005; Sheard & Golby, 2006), posttests were more competitive than pretests (A. Miller & Donohue, 2003), or pre-existing groups demonstrated substantial differences in pretest performance (Okwumabua, Meyers, Schleser, & Cooke, 1983). Nineteen studies (41%) blinded participants of the research question, three studies used blinded outcome assessors (7%), three studies satisfied both of these criteria (7%), and 21 studies (46%) did not state using blinding procedures. All of the studies were judged to have used a valid measure of endurance performance, but only seven studies (15%) referred to the measure's reliability. Withdrawal and dropout information were reported in 11 studies (24%). Concerns with intervention integrity were identified in nine studies (20%).

Study and Participant Characteristics

Thirty-eight studies (83%) used group designs, and eight studies (17%) used single-subject designs. Twenty-nine studies (63%) were conducted in a laboratory setting, and 17 studies (37%) were conducted in a field setting. The studies measured running (*n* = 23), cycling (*n* = 14), swimming (*n* = 4), gymnasium triathlon (*n* = 2), rowing (*n* = 2), and walking (*n* = 1) performance using time trials (alone or in a group, *n* = 25), incremental tests (*n* = 10), constant-workload tests (*n* = 6), constant-duration tests (*n* = 4), and points won in competition (*n* = 1). Distances in time trials ranged from 1.5 kilometres (km) to 20 km in cycling, 1 km to 5 km in running, and 100 metres to 1,000 yards (914 metres) in swimming. The number of participants per study ranged from one to 90 (mean ± standard deviation (SD) = 27 ± 25). The number of males ranged from zero to 60 (mean ± SD = 17 ± 16), and the number of females ranged from zero to 45 (mean ± SD = 11 ± 14). Twenty-one studies (46%) chose a sample of athletes, who ranged in ability from high-school to nationally-ranked athletes. Two studies (Lindsay et al., 2005; Sheard & Golby, 2006) chose competitive athletes and measured endurance performance in actual competition. Eleven studies (24%) considered moderating variables.

Practical Psychological Interventions

Twenty-five studies measured the effect of a psychological intervention that was judged to be ethical, feasible, and accessible to a sport practitioner, coach, or athlete. Across these 25 studies, 46 interventions were included. With consideration to potential mediating variables, eight studies (32%) measured psychological variables, three of these studies (Barwood, Corbett, Wagstaff, McVeigh, & Thelwell, 2015; Blanchfield, Hardy, de Morree, Staiano, & Marcora, 2014; Lindsay et al., 2005) explicitly targeted the psychological variable with the intervention, and four interventions that enhanced endurance performance appeared to reduce perception of effort (Barwood et al., 2015; Barwood, Thelwell, & Tipton, 2008; Blanchfield, Hardy, de Morree, et al., 2014; Morgan, Horstman, Cymerman, & Stokes, 1983). Eleven studies (44%) clearly included a social-validity or consumer-satisfaction measure, and two studies (Barwood et al., 2015; Okwumabua et al., 1983) included a placebo control group. Three studies referred to the qualifications or the experiences of the person delivering (Lindsay et al., 2005; Post, Muncie, & Simpson, 2012) or overseeing (Barwood et al., 2008) the intervention. The interventions were organised into eight categories, and each category is summarised separately. Table A2 (Appendix E, p. 267) provides additional details on each intervention.

Association and dissociation. Participants were encouraged to use an associative or dissociative cognitive strategy in five studies (one strong quality, two moderate, and two weak), and the findings were mixed. The strong-quality study found that a dissociative cognitive strategy increased walking time to exhaustion (Δ = 1.06) in 11 of 14 (79%) army males performing in an incremental test (Morgan et al., 1983). Although the dissociation group performed for 48% longer than a control group, ratings of perceived exertion were similar in the final minute of performance, which suggests that dissociation may have slowed the increase in perception of effort. Each of the other four studies compared the effects of multiple interventions. An associative cognitive strategy improved non-athletes' 1.5-mile running performance to a greater extent than a dissociative strategy, pre-performance psyching up, and no intervention (Saintsing, Richman, & Bergey, 1988), but non-athletes who used associative, dissociative, or positive self-talk strategies ran similar distances in 30 minutes to a control group (Weinberg, Smith, Jackson, & Gould, 1984). In a single-subject, multiple-baseline design (L. M. Scott et al., 1999), university rowers who listened to an associative audiotape (Δ = 6.58, PND = 100%) showed a greater increase in the distance rowed during 40 minutes than those who dissociated by watching a videotape (Δ = 1.63, PND = 92%) or listening to music (Δ = 0.57, PND = 30%). Finally, association (Δ = 0.46) and dissociation (Δ = 0.88) improved non-athletes' 1.5-mile running performances compared with those of participants who were given relaxation exercises as a placebo (Okwumabua et al., 1983), but baseline running times suggested that the groups were not equivalent. Of the five studies, none included a social-validity measure completed by the participants, although a coach reported that rowers who used association developed superior rowing technique than those who used dissociation (L. M. Scott et al., 1999). Performances were not competitive, and moderating variables were not considered. Although two studies (Morgan et al., 1983; Weinberg et al., 1984) measured psychological variables, none targeted potential mediating variables.

Goal setting. Goal setting enhanced endurance performance in two studies (combined $\Delta = 0.34$). High-school runners who were assigned easy, challenging, and unrealistic combinations of short-term and long-term goals showed similar levels of improvement in their 2.3-km running times ($\Delta = 0.36$) in simulated competition (Tenenbaum, Spence, & Christensen, 1999). The amount of improvement was correlated with both ego orientation ($r = .39$) and task orientation ($r = .38$). A second, moderate-quality study found that non-athletes cycled for longer during an incremental test ($\Delta = 0.33$) when they set themselves a goal for improved endurance performance and then received feedback on the lapsed performance time (Theodorakis et al., 1998). Neither study targeted psychological mediating variables.

Hypnosis. Hypnosis interventions enhanced endurance performance in two studies (one moderate quality and one weak). Hypnotised non-athletes who listened to a motivational passage increased their performance time in a running incremental test, but a no-intervention control group did not (Jackson et al., 1979). Of the hypnotised participants, those who demonstrated high hypnotic susceptibility improved their endurance performance ($\Delta = 0.80$), but those who demonstrated low susceptibility did not ($\Delta = 0.13$). Additionally, the improvement of high-susceptibility participants was not significantly greater than the improvement of non-hypnotised participants who listened to the same passage. A second study, which used a single-subject, multiple-baseline design, found that hypnosis led to two of three nationally-ranked cyclists winning more points in competitive road races (Δ = 1.85, PND = 52%). The intervention was designed to increase the intensity of the flow state, and it was delivered by a researcher trained in hypnotic techniques (Lindsay et al., 2005).

Imagery. Imagery enhanced endurance performance in one of two studies (both moderate quality). Non-athletes who used pre-performance imagery of skill execution, successful performance outcomes, or both showed improvements in 1.5-mile running performance similar to those of a control at the second of two posttests (Burhans, Richman, & Bergey, 1988). In a study that used a single-subject, multiple-baseline design, imagery training and listening to a recording of an imagery script improved three of four competitive youth swimmers' performances (Δ = 3.32, PND = 75%) in a 1,000-yard practice set (Post et al., 2012). The imagery training was delivered by a researcher who had experience delivering imagery interventions. Neither study targeted psychological mediating variables.

Pre-performance statements. Pre-performance interventions involving instructional or motivational statements improved middle-distance running performance (combined Δ = 0.24) in four studies (two moderate quality and two weak). Participation in a group motivational exercise (Δ = 0.10) (Donohue et al., 2006) and motivational and instructional statements delivered by headphones (Δ = 0.09) (A. Miller & Donohue, 2003) improved high-school distance runners' performances in a one-mile run. These interventions also led to greater improvements in endurance performance than yoga exercises and a self-selected song, respectively. In the latter study, however, participants raced in more competitive trials in the posttest, meaning that some improvement in all conditions might be attributable to competition. A third study found that collegiate cross-country runners who listened to statements through headphones significantly improved their one-mile run performances in three of six intervention conditions (Δ ranged from 0.03 to 0.18) (Weinberg, Miller, & Horn, 2012). Finally, motivational statements (Δ = 1.89), instructional statements (Δ = 2.11), and questions about what participants were thinking and feeling (Δ = 1.33), delivered by research assistants, improved six collegiate cross-country runners' performances in a 1-km run (Donohue et al., 2001). Each of the four studies assessed participants' satisfaction with the intervention, one intervention improved endurance performance in simulated competition (A. Miller & Donohue, 2003), and one study (A. Miller & Donohue, 2003) considered moderating variables. None of these studies targeted psychological mediating variables or included multiple posttests. In all four studies, participants chose statements after the baseline performance, and only those assigned to certain experimental conditions used all of the statements; this suggests that there could have been subsequent contamination or co-intervention effects.

Psychological skills training packages. Psychological skills training packages enhanced endurance performance in five studies (two moderate quality and three weak). First, PST enhanced the competitive performances of some national-level youth swimmers. Across all competitive distances, 23 of 33 participants (70%) improved their performance following the intervention. Across the five endurance-distance events, however, PST improved group-level endurance performance for those who competed one-month post-intervention (Δ = 0.28), but it did not improve the performances of those who competed immediately post-intervention (Δ = 0.03) (Sheard & Golby, 2006). Second, PST increased the distance ran by non-athletes during 90 minutes in the heat (Δ = 0.54) without increasing ratings of perceived exertion (Barwood et al., 2008). Furthermore, PST improved the 1,600-metre running performances of athletes of varying abilities (Patrick & Hrycaiko, 1998) and non-athletes' performances in gymnasium triathlons (Thelwell & Greenlees, 2001, 2003). The interventions improved endurance performance for all 13 participants in studies that used single-subject, multiple-baseline designs (Δ = 3.70, PND = 84%), and these improvements were maintained in three to eight posttests (Patrick & Hrycaiko, 1998; Thelwell & Greenlees, 2001, 2003). Psychological skills training was somewhat beneficial in actual competition (Sheard & Golby, 2006), and it improved endurance performance in simulated head-to-head competition (Thelwell & Greenlees, 2003). Four studies presented support for the social validity of the intervention (Patrick & Hrycaiko, 1998; Sheard & Golby, 2006; Thelwell & Greenlees, 2001, 2003). The PST packages were not compared to alternative interventions, and moderating variables were not considered. Two studies (Barwood et al., 2008; Sheard & Golby, 2006) measured psychological variables, but psychological mediating variables were not explicitly targeted.

Relaxation and biofeedback. A six-week training program using relaxation and biofeedback improved the running economy of sub-elite, long-distance runners (Caird et al., 1999). Peak running velocity was measured to monitor changes in fitness, but it did not change.

Self-talk. Self-talk interventions enhanced endurance performance in four of five studies (three moderate quality and two weak). Motivational self-talk reduced perception of effort and increased cycling time to exhaustion for 10 of 12 (83%) non-athletes ($\Delta = 0.66$) (Blanchfield, Hardy, de Morree, et al., 2014), and it improved non-athletes' performances in a 10-km cycling time-trial compared with neutral self-talk ($\Delta = 0.39$) (Barwood et al., 2015). Non-athletes who used positive self-talk, however, ran similar distances in 30 minutes to participants who used association, dissociation, or no strategy (Weinberg et al., 1984). In a study using a single-subject, multiple-baseline design, positive self-talk statements used with ($\Delta = 4.56$, PND = 100%) or without ($\Delta = 2.35$, PND = 100%) audiotape assistance increased the amount of work completed by non-athletes during 20 minutes of cycling (Hamilton, Scott, & MacDougall, 2007). Negative self-talk statements did not improve endurance performance ($\Delta = 0.48$, PND = 37%). A fifth study found that nationally-ranked swimmers swam faster training times when they were using positive thinking (e.g., “I’m doing great”), mood words (e.g., “blast”), or task-relevant thinking (e.g., “elbows up”) than when they were thinking “normally” (Rushall & Shewchuk, 1989). As each swimmer was trained in each intervention, however, the control condition might have been contaminated by a strategy that they had learned previously, and the swimmers may have used multiple interventions together (i.e., co-intervention). Of the five studies, none considered moderating variables, none included a social-validity measure, and none measured competitive performance. Two studies targeted perception of effort as a mediating variable (Barwood et al., 2015; Blanchfield, Hardy, de Morree, et al., 2014). The four group-design studies included only one posttest.

Additional Psychological Determinants

Twenty-one located studies examined the effects of additional psychological interventions on endurance performance; these interventions were categorised as external motivators (*n* = 10), mental fatigue (*n* = 3), priming interventions (*n* = 3), experimenter effects (*n* = 3), emotion suppression (*n* = 1), and efficacy strength (*n* = 1). Fourteen studies measured potential mediating variables, which were measures of perceived effort during endurance performance in 13 studies. The findings relating to each psychological determinant are summarised separately.

External motivators. Ten studies (eight moderate quality and two weak) examined the effects of head-to-head competition, verbal encouragement, financial incentives, or co-participation on endurance performance. Competition (combined Δ = 0.32) and verbal encouragement (combined Δ = 1.22) generally enhanced endurance performance. Head-to-head competition improved endurance performance in constant-workload tests (Higgs, 1972; Wilmore, 1968), and it improved time-trial performance in one of two studies (Corbett, Barwood, Ouzounoglou, Thelwell, & Dicks, 2012; Peveler & Green, 2010). On the basis of reported data, 29 of 34 non-athletes (85%) performed better when competing. Verbal encouragement improved performance in an incremental test in two studies. Specifically, competitive runners (Δ = 2.73) and non-athletes (Δ = 1.58) ran for longer in a verbal-encouragement condition (Moffatt, Chitwood, & Biggerstaff, 1994). Type-B personality non-athletes (Δ = 0.45), but not Type-A non-athletes (Δ = 0.03), also ran for longer when encouraged (Chitwood, Moffatt, Burke, Luchino, & Jordan, 1997). A financial incentive did not affect regional-level cyclists' performances in a time trial (Hulleman, De Koning, Hettinga, & Foster, 2007), but a combined intervention of encouragement and incentives improved university endurance athletes' performances in an incremental running test (Δ = 0.40) (Viru et al., 2010). Performing a time trial with another participant (without instructions to compete) did not affect (Δ = -0.07) running performance (Bath et al., 2012), but performing with a visual representation of another participant did improve (Δ = 0.26) cycling time-trial performance (E. L. Williams et al., 2015). Psychological mediating variables were unclear in these 10 studies.

Mental fatigue. Mental fatigue undermined endurance performance in three studies (one strong quality and two moderate). In a strong-quality study, 13 of 16 non-athletes (81%) demonstrated reduced time to exhaustion (Δ = -0.34) following a prolonged and demanding cognitive task (Marcora et al., 2009). The same intervention also led to slower running times (Δ = -0.27) in a 3-km time trial (MacMahon, Schücker, Hagemann, & Strauss, 2014). Furthermore, performing a demanding cognitive task that required response inhibition caused slower performance times in a 5-km running time trial (Δ = -0.34) compared to a similar task without response inhibition (Pageaux, Lepers, Dietz, & Marcora, 2014). The pre-performance, mentally-fatiguing tasks increased perception of effort during subsequent endurance performance in all three studies.

Priming. The effects of priming interventions on endurance performance were examined in three studies (all moderate quality). Two experiments examined the effects of subliminally-presented visual cues on cycling time to exhaustion (Blanchfield, Hardy, & Marcora, 2014). Happy faces reduced perception of effort and led to eight of 13 participants (62%) performing for longer (Δ = 0.26) compared with sad faces (Experiment 1), and action words reduced perception of effort and increased time to exhaustion compared with inaction words in a single-subject experiment (Experiment 2). A third study found that rowers who were primed for an autonomy motivation orientation performed faster than control-primed and impersonally-primed rowers (Hodgins, Yacko, & Gottlieb, 2006).

Experimenter effects. Three studies (all moderate quality) examined the effects of experimenter characteristics and experimenter behaviours on performance in an incremental walking/running test. An experimenter's sex influenced non-athletes' endurance performance, depending on the sex and race of participants, but endurance performance was not affected by whether participants and the experimenter were friends (Bubb et al., 1985). Talking to non-athletes during the test did not affect endurance performance (Δ = -0.10) (Franks & Myers, 1984, Study 1).

Emotion Suppression. Instructing endurance athletes to conceal their emotions whilst watching a disgusting video led to an increase in ratings of perceived exertion and a poorer performance in a subsequent 10-km time trial (Δ = -0.34) compared with watching the video without instructions (Wagstaff, 2014).

Efficacy strength. Youth swimmers with high efficacy strength performed better in simulated competition than those with low efficacy strength (M. Miller, 1993). Efficacy strength was manipulated by assigning a goal that was faster (low efficacy strength) or slower (high efficacy strength) than their personal best.

Discussion

A systematic literature review was conducted to identify psychological determinants of endurance performance. First, this review identified 25 studies that examined the effects of practical psychological interventions on endurance performance. These psychological interventions were judged to be ethical, feasible, and accessible to a sport practitioner, coach, or athlete. Consistent support was found for using imagery, self-talk, and goal setting to enhance endurance performance, but it is unclear whether learning multiple psychological skills is more beneficial than learning one psychological skill. Twenty-one additional studies were identified that drew attention to other psychological interventions that affect endurance performance. Studies consistently showed that mental fatigue undermines endurance performance, and verbal encouragement and head-to-head competition can have a beneficial effect.

Practical Psychological Interventions

Overview. This review found substantial support for using practical psychological interventions to enhance endurance performance. Association, dissociation, goal setting, hypnosis, imagery, pre-performance statements, PST packages, and self-talk were found to improve performance in endurance tasks. Of the 24 studies that aimed to improve endurance performance, 22 found that at least one intervention improved performance. With the exception of research conducted on association and dissociation, however, none of the studies compared the effects of these different interventions on endurance performance. For example, PST packages were not compared against their individual components (i.e., goal setting, imagery, relaxation, or self-talk) and only one study (Weinberg et al., 1984) compared a PST intervention (positive self-talk) to alternative interventions (association and dissociation). Therefore, and because only one study (Morgan et al., 1983) was classed as strong in quality, it is difficult to draw a strong conclusion about whether one practical psychological intervention should be chosen over others. There was, however, consistent support for PST packages, with five studies finding that PST packages improved endurance performance across three sports, with athletes, in real-life and simulated competition, and in multiple posttests (Barwood et al., 2008; Patrick & Hrycaiko, 1998; Sheard & Golby, 2006; Thelwell & Greenlees, 2001, 2003). The relative contribution of each intervention component is not known (Barwood et al., 2008), however, and support was also found for goal setting, imagery, and self-talk interventions in isolation. Therefore, a PST package might be more time consuming for an athlete without further improving their endurance performance. A cautious comparison of effects sizes and PND values does not suggest that there are substantial additive effects, although teaching multiple psychological skills could be advantageous if they allow athletes to choose one or more psychological skill that complements their needs and preferences.

Psychological mediating variables. Although many practical psychological interventions improved endurance performance, little is known about the psychological mechanisms underlying these improvements. Surprisingly, only three practical psychological intervention studies (Barwood et al., 2015; Blanchfield, Hardy, de Morree, et al., 2014; Lindsay et al., 2005) appeared to target and measure psychological mediating variables. Understanding mediating variables could help sport practitioners and athletes to choose an intervention that might be particularly valuable for that athlete. For example, an intervention that increases self-efficacy could be useful for an athlete who doubts the attainability of their goals during the most demanding periods of a race. Additionally, understanding mediating variables could help a coach or practitioner to adapt the intervention to meet the needs of the athlete, whilst maintaining the “essence” or intention of the chosen intervention. Measuring mediating variables could also help researchers understand why an intervention was not efficacious for a proportion of participants; that is, the intervention might have had an inconsistent effect on the mediating variable. The findings of this review suggest that practical psychological interventions aimed at increasing motivation, increasing efficacy strength, or reducing perception of effort could enhance endurance performance. Researchers could therefore design an intervention that targets these psychological constructs or examine the effect of an intervention on measures of these psychological constructs. Psychological theories could also determine which psychological constructs are targeted and measured. As explained below (Theoretical Implications section, p. 82), the lack of theoretically-informed interventions could account for the paucity of studies investigating psychological mediating variables.

Placebo control conditions. Increased expectations of performance improvement might account for the effects of some psychological interventions. The placebo effect refers to a favourable outcome that arises purely from a person's belief that they have received a beneficial treatment (Clark, Hopkins, Hawley, & Burke, 2000). A literature review (Beedie & Foad, 2009) reported placebo effects of varying magnitudes from studies that measured the performance of sub-elite athletes in strength, pain-tolerance, and endurance tasks ranging from 1-km running to 40-km cycling. Similarly, a meta-analysis of 14 studies reported a moderate effect size (0.40) for the placebo effect on performance across exercise modes and a small effect size (0.22) for performance in endurance exercise (Bérdi et al., 2011). In the present review, nine of the 20 effect sizes (Donohue et al., 2006; A. Miller & Donohue, 2003; Sheard & Golby, 2006; Weinberg, Miller, et al., 2012) calculated for practical psychological interventions in group-design studies without a placebo control condition were less than 0.22. As well as expecting to improve, participants might believe that the researchers hope or expect that they will perform better post-intervention, and they might therefore offer different amounts of effort in these performance tests (i.e., demand characteristics) (Patrick & Hrycaiko, 1998). It is difficult to judge the contribution of expectation effects in this review, because only two studies (Barwood et al., 2015; Okwumabua et al., 1983) included a placebo control condition. Additionally, some of the included studies (Jackson et al., 1979; Morgan et al., 1983; Patrick & Hrycaiko, 1998) appeared to heighten participants' expectations of performance improvement through the wording of instructions they gave (Beedie & Foad, 2009). Furthermore, relatively few studies used research assistants who were blinded to participants' allocation, deceived participants about the research question, played down the likely benefits of the intervention (if necessary), or looked at the endurance performance of high-level and motivated athletes in competition; each of these factors might increase the likelihood of expectation effects in the included studies (Clark et al., 2000). It is acknowledged that enhanced expectations can be an important component of a performance-enhancement intervention. Nevertheless, it is important for the credibility of sport psychology as a profession that recommended psychological interventions are shown to have greater effects than the expectations they instil in athletes. Unlike other sport science disciplines (e.g., nutrition), psychologists are unable to create a placebo treatment by removing the key ingredients from an intervention. Instead, researchers could compare psychological interventions to alternative control treatments (W. Borg, 1984) or inert solutions, pills, or capsules that are described as beneficial for endurance performance. Alternative control treatments are similar in duration, perceived value, and procedure to the experimental treatment, but they target unrelated dependent variables (W. Borg, 1984). Researchers should also measure each participant's expectation of performance improvement (Boot, Simons, Stothart, & Stutts, 2013).

Limitations of included studies. Additional limitations were consistently identified across the included studies investigating the effects of practical psychological interventions on endurance performance. Only six of the 18 studies that chose group designs reported using random assignment to experimental and control groups, which is an indicator of strong experimental research (Campbell & Stanley, 1966). None of these six studies, however, measured the endurance performance of athletes in competition. Andersen (2009) argued that few randomised controlled trials have shown that psychological interventions improve the performances of athletes in competition. Further, there are few sport psychology intervention studies that have measured the performance of athletes in competition (G. L. Martin et al., 2005). Illustrating this point, only two of the included studies (Lindsay et al., 2005; Sheard & Golby, 2006) examined the effects of an intervention for athletes in real-life competition. These interventions were inconsistent in improving endurance performance, perhaps because of confounding variables (e.g., the specific competition) or because the margins for improvement are small for trained athletes in competition. Alternatively, the benefits of practical psychological interventions for competitive athletes might not be observable in their short-term competitive performances. Instead, psychological strategies that help athletes to improve their performances in training—where performance incentives are likely lower—could lead to meaningful long-term improvements in competitive performances through a physiological mechanism (e.g., adaptation) or a psychological mechanism (e.g., increased self-efficacy). Nevertheless, research that measures endurance performance in competition could complement well-controlled studies by demonstrating whether the effects of psychological interventions generalise to real-life performance. It is acknowledged that athletes and their gatekeepers (e.g., coaches) might be hesitant to accept that only a proportion of the athletes will receive a potentially-beneficial intervention. Researchers, athletes, and gatekeepers might therefore agree that control participants will be offered the intervention after data collection has been completed.

The long-term benefits of practical psychological interventions are unclear. For example, none of the studies that delivered instructional or motivational statements before performance included multiple posttests, and the novelty of these and other interventions might wear off. Alternatively, continued practice of a psychological skill could lead to additional improvements in endurance performance. Identified group-design studies did not include more than two posttests, and the second posttest was conducted up to one month after the first posttest (Burhans et al., 1988; Sheard & Golby, 2006). Single-subject, multiple-baseline studies included up to nine post-intervention performances (Lindsay et al., 2005), and these studies typically demonstrated that improvements in endurance performance were maintained. Nevertheless, the effects of practical psychological interventions on endurance performance after three or more months are unknown. It would be valuable to know if participants maintained their improvements in endurance performance, but it would also be difficult to attribute long-term changes in endurance performance to the intervention. Therefore, it would also be valuable to know whether participants continued to use the taught intervention after they finished their commitment to the study (Patrick & Hrycaiko, 1998; Thelwell & Greenlees, 2001), which could provide insight into long-term adherence and perceived intervention value. None of the studies reported this information.

When participants were required to make a commitment to a practical psychological intervention, 12 of the studies (67%) did not report the number and reasons for withdrawals and dropouts. This information is important, because participants might drop out when they do not believe that an intervention will be beneficial, when an intervention is not enjoyable, or when an intervention is perceived to be inconvenient or too much work. Therefore, dropouts could lead to an inflated mean improvement in the experimental condition. Furthermore, only three studies referred to the experience or qualifications of the person performing (Lindsay et al., 2005; Post et al., 2012) or overseeing (Barwood et al., 2008) the intervention. This information would be valuable so that readers can judge whether the expertise of this person influenced the effects of the intervention. Similarly, practitioners could judge whether they have sufficient expertise to deliver the intervention.

Additional Psychological Determinants

External motivators, mental fatigue, priming, emotion suppression, efficacy strength, and the experimenter's sex affected endurance performance. In particular, experimental research consistently demonstrates that mental fatigue undermines endurance performance, whereas external motivators typically have a beneficial effect on endurance performance. Mental fatigue, induced by prolonged and demanding cognitive tasks, consistently increased perception of effort and had a detrimental effect on endurance performance (MacMahon et al., 2014; Marcora et al., 2009; Pageaux et al., 2014). As external motivators, head-to-head competition (Corbett et al., 2012; Higgs, 1972; Wilmore, 1968), verbal encouragement (Chitwood et al., 1997; Moffatt et al., 1994), and a combined intervention of financial incentives and verbal encouragement (Viru et al., 2010) enhanced performance in various endurance tasks, although the introduction of a financial incentive did not affect endurance performance (Hulleman et al., 2007). It is difficult to establish how these interventions enhanced endurance performance and to explain the inconsistencies in results, because the effects of the interventions on psychological variables were not determined in these studies. Although head-to-head competition and verbal encouragement might increase participants' motivation to perform, these interventions might also act as sources of self-efficacy (vicarious experience and verbal persuasion, respectively, e.g., Bandura, 1982), or they could reduce perception of effort. Measuring these mediating variables could clarify the psychological mechanisms underlying the observed effects on endurance performance. Finally, endurance performance can be affected by priming interventions (Blanchfield, Hardy, & Marcora, 2014; Hodgins et al., 2006); additional research is required, however, to determine whether these interventions offer a feasible means of performance enhancement.

Theoretical Implications

Psychological theories can help researchers to identify key factors that determine behaviour (e.g., endurance performance) and that can be targeted by novel or refined interventions (Michie & Prestwich, 2010). In the research area of endurance performance, theoretically-informed studies could identify the psychological mechanisms through which interventions affect endurance performance, and researchers and practitioners could target these mechanisms with interventions. Theoretically-informed interventions might therefore produce greater or more consistent effects (Michie & Prestwich, 2010). Of the 46 included studies, only three studies examining practical psychological interventions (Barwood et al., 2015; Blanchfield, Hardy, de Morree, et al., 2014; Post et al., 2012) and eight studies examining additional psychological determinants (Blanchfield, Hardy, & Marcora 2014, Experiments 1 and 2; Hodgins et al., 2006; MacMahon et al., 2014; Marcora et al., 2009; M. Miller, 1993; Pageaux et al., 2014; Wagstaff, 2014) were clearly informed by psychological theory (24% overall). Of these 11 studies, seven studies were informed by the psychobiological model of endurance performance, which demonstrates that few psychological theories have been applied to endurance performance. Further, only 22 of the 46 included studies (48%) measured psychological variables. The intervention-performance psychological mechanism was therefore unclear in many studies. For example, post-hypnotic suggestion (Jackson et al., 1979), goal setting (e.g., Theodorakis et al., 1998), head-to-head competition (e.g., Corbett et al., 2012), and verbal encouragement (e.g., Moffatt et al., 1994) affected endurance performance, but the effects of these interventions on psychological variables were not determined. Theoretically-informed research that measures psychological mediating variables is highly encouraged.

The psychobiological model of endurance performance predicts that any psychological intervention that increases potential motivation (the greatest amount of effort that a person would be willing to offer to satisfy a motive) or reduces perception of effort (how effortful, heavy, or strenuous the exercise feels) will enhance endurance performance, and any psychological intervention that reduces potential motivation or increases perception of effort will undermine endurance performance (Marcora et al., 2008). In support of the psychobiological model, motivational self-talk (Barwood et al., 2015; Blanchfield, Hardy, de Morree, et al., 2014), a PST package (Barwood et al., 2008), and dissociation (Morgan et al., 1983) appeared to reduce perception of effort and enhanced endurance performance, mentally-fatiguing tasks (MacMahon et al., 2014; Marcora et al., 2009; Pageaux et al., 2014) and emotion suppression (Wagstaff, 2014) increased perception of effort and undermined endurance performance, and subliminally-presented visual cues (Blanchfield, Hardy, & Marcora, 2014) influenced both perception of effort and endurance performance in the directions predicted by the psychobiological model. Although interventions that could be expected to increase potential motivation such as verbal encouragement (e.g., Moffatt et al., 1994), head-to-head competition (e.g., Corbett et al., 2012), and goal setting (e.g., Theodorakis et al., 1998) enhanced endurance performance, no included studies examined the effect of manipulating potential motivation.

In the present review, five studies explicitly examined the effects of traditional associative and dissociative cognitive strategies on endurance performance (Morgan et al., 1983; Okwumabua et al., 1983; Saintsing et al., 1988; L. M. Scott et al., 1999; Weinberg et al., 1984). Traditional classifications of attentional focus proposed that athletes who use an associative strategy monitor their bodily sensations and use this feedback to adjust their pace; athletes who dissociate direct their attention away from these uncomfortable sensations (Morgan & Pollock, 1977). More recent theoretical perspectives, however, argue that attentional strategies can be categorised more precisely (Brick et al., 2014; Stevinson & Biddle, 1999). Brick and colleagues (2014) recently proposed a five-category model of attentional activity. According to this model, athletes “actively self-regulate” when they attempt to control or monitor their thoughts, feelings, or actions. These associative strategies can allow an athlete to optimise their pace or efficiency of movement without elevating perception of effort. Examples of active self-regulation strategies include self-talk and relaxation strategies that are used during endurance performance (Thelwell & Greenlees, 2003) and pre-performance, mental-preparation strategies such as setting process goals (A. Miller & Donohue, 2003) and visualising successful execution of skills (Post et al., 2012). The findings of the present review suggest that active self-regulation strategies could be valuable for athletes who aim to optimise their endurance performance.

Implications and Recommendations for Practice

Psychological skills training interventions involving imagery, self-talk, and goal setting offer a promising method for enhancing the performance of endurance athletes. Although the psychological mechanisms underlying the effects of these interventions were typically not measured, these interventions consistently improved performance in different endurance sports. Studies that were rated as being at less risk of bias suggest that developing a personalised imagery script that could include executing good technique and overcoming fatigue could be efficacious. Setting process goals (e.g., increasing pace during early sections of an event and maintaining pace during later sections) and performance goals (e.g., a finishing time) for an upcoming performance, and identifying motivational statements to use during different sections of the performance and to counter negative thoughts could also be efficacious (Barwood et al., 2008, 2015; Blanchfield, Hardy, de Morree, et al., 2014; Post et al., 2012). Practitioners applying these findings should tailor them to the individual needs and preferences of the athlete and the demands of the endurance sport (Post et al., 2012; Taylor, 1995). As mental fatigue increases perception of effort and undermines endurance performance, endurance athletes should avoid mentally-draining activities before they compete. For example, endurance athletes should avoid situations that require them to suppress their emotions or behaviour (Muraven, Tice, & Baumeister, 1998; Wagstaff, 2014), which could include interviews with the media. As a further suggestion, coaches could use head-to-head competition and verbal encouragement during training to facilitate maximum effort when required.

Music could be valuable during training, as well as events and competitions that permit its use. Although excluded from this review, there is substantial evidence that music can enhance endurance performance (Karageorghis & Priest, 2012a, 2012b). Self-selecting music for its motivational qualities is encouraged (Karageorghis & Priest, 2012a, 2012b). The benefits of music, however, should be weighed against potential risks, such as not hearing safety-related cues (e.g., road traffic), distraction from technique, or distraction from pacing-related cues (e.g., exercise sensations and other competitors). Placebos and various forms of deceptive feedback can also be used to enhance endurance performance; the practical application of these interventions during training and competitions, however, raises significant ethical issues (Halson & Martin, 2013; H. S. Jones et al., 2013).

Implications and Recommendations for Research

Theoretically-driven studies could systematically examine the mechanisms through which psychological interventions affect endurance performance, and they could therefore encourage development and refinement of performance-enhancement interventions that have consistent and substantial effects in endurance events. Research examining the effects of interventions in real-life competition could particularly add to the endurance literature. Researchers are also encouraged to compare different performance-enhancement psychological interventions using randomised, controlled experiments. Inclusion of placebo control conditions could help readers to judge the effects of interventions beyond expectation effects. Furthermore, these studies should include more than one posttest, report whether participants continue to use the intervention following their commitment to the study, report the number of participants who drop out from the study and their reasons for doing so, and provide expertise-related information on the person delivering the intervention.

As an alternative to measuring performance in real-life endurance competition, researchers could use head-to-head competition and verbal encouragement to ensure that participants offer maximum effort during an endurance task. This could help researchers to test the effects of interventions when participants are in motivated performance situations. To reduce the risk of confounding variables, care should be taken to apply head-to-head competition and verbal encouragement consistently across experiment trials. For example, a research assistant who is blinded to the study aims or hypotheses could provide verbal encouragement using a consistent verbal encouragement protocol (Andreacci et al., 2002), a blinded and independent researcher could analyse audio recordings of the delivered verbal encouragement and attempt to predict the experimental conditions, and head-to-head competition procedures could be standardised (e.g., Corbett et al., 2012).

Few practical psychological interventions appeared to be designed specifically for the psychological demands of endurance sports. More often, interventions were informed by research on mental preparation or research on interventions across a range of sports. This is surprising, because endurance sports have particular psychological demands, such as experiencing pain, that should be taken into account when an intervention is being designed (Taylor, 1995). Qualitative research has drawn some attention to the psychological demands faced by endurance athletes (Buman et al., 2008;

Hollander & Acevedo, 2000; Holt et al., 2014; Kress & Statler, 2007). Future research could shed greater light on the psychological demands facing endurance athletes or test interventions that are designed to help athletes to cope with these demands.

It is surprising that only four studies (MacMahon et al., 2014; Marcora et al., 2009; Pageaux et al., 2014; Wagstaff, 2014) examined interventions that undermine endurance performance. Ethically-approved research that is conducted in controlled laboratory settings could examine the effects of additional psychological states (e.g., threat states), psychological strategies (e.g., thought suppression), and situations that endurance athletes encounter (e.g., encountering pre-performance stressors) that could be debilitative to performance.

Little is known about whether participant characteristics influence the effects of psychological interventions. The results shed little light on whether gender (Bubb et al., 1985; Burhans et al., 1988; Franks & Myers, 1984; A. Miller & Donohue, 2003) or athletic ability (M. Miller, 1993; Moffatt et al., 1994) are moderating variables. Nevertheless, A/B personality type appears to affect participants' responses to verbal encouragement (Chitwood et al., 1997), participants with high task and ego orientations respond more favourably to goal-setting interventions (Tenenbaum et al., 1999), and hypnotic susceptibility influences whether hypnosis-based interventions enhance endurance performance (Jackson et al., 1979). Further research on moderating variables, such as competitive level, competitive distance, or achievement-goal orientation, could shed light on whether certain interventions are particularly beneficial for specific groups of athletes, and this evidence base could increase the effects of psychological interventions.

Lack of blinding procedures was often a source of bias. Researchers who are aware of the intervention status of participants might unintentionally affect participants' performance expectations. Where resources are available, researchers are encouraged to collect data using research assistants who are blinded to treatment allocation, particularly when verbal encouragement is given during endurance performance. It is acknowledged that researchers may be unable to disguise the research question when they are testing the effects of an intervention. Researchers could therefore inform participants that they do not know what impact (if any) the intervention will have on their endurance performance (Post et al., 2012), or they could include an alternative control treatment (W. Borg, 1984).

Finally, researchers could consider a more diverse range of sports and distances. No located studies examined rowing or triathlon performance in field settings, and no research was located on endurance-distance race walking, speed skating, or cross-country skiing. There is also a lack of studies examining the effects of interventions in long-distance events (e.g., half marathons, open-water swims, ultra-distance events); only two studies (Barwood et al., 2008; Lindsay et al., 2005) measured performance in endurance tasks that took longer than one hour to complete.

Limitations of the Systematic Review

This literature review synthesised studies on the psychological determinants of endurance performance. A heterogeneous selection of studies were included, and there are insufficient studies to provide sport- or distance-specific guidance. Outcome measures that range from 100-metres breaststroke swimming (Sheard & Golby, 2006) to ultra-endurance events (e.g., ultramarathons) could satisfy the chosen definition of endurance performance. The technical, physical, logistical, and mental demands (Taylor, 1995) of the included sports and distances will undoubtedly vary, and the comparability of these performance measures could therefore be questioned. Individual differences also need to be taken into account; interventions seemed influential for only a proportion of group-design participants. While the findings of this systematic review should inform evidence-based practice, practitioners interested in performance enhancement should also consider the demands of the specific sport and competitive distance, as well as the needs of the individual athlete (Taylor, 1995).

This systematic review synthesised the peer-reviewed studies that have been published to date, because these studies comprise the evidence base that is available to practitioners, theorists, and researchers. Publication bias might partially account for the abundance of interventions that significantly affected endurance performance, because studies might not have been put forward or accepted for publication if the examined intervention did not have an effect (Petticrew & Roberts, 2006). Indeed, a recent study reported statistical evidence that publication bias is a pervasive problem across all areas of psychological research (Kühberger, Fritz, & Scherndl, 2014). Specifically, this study found a negative correlation between effect size and sample size, as well as a disproportionately high number of *p* values that just passed the boundary of statistical significance, which indicate that it is mainly the statistical significance of findings that determines whether a study is published.

Each included study was evaluated using a modified version of the EPHPP Quality Assessment Tool for Quantitative Studies (B. H. Thomas et al., 2004). This evaluation tool is not specific to the sport context, and it was therefore modified. The tool evaluates information that is reported in the manuscript, and reporting practices could vary between public health and sport science. Nevertheless, sport science researchers are encouraged to report randomisation and blinding procedures when performed and the numbers and reasons for withdrawals and dropouts, because this information is important for judging bias. An evaluation tool that is specific to sport science research and sensitive to its research practices would be valuable. Similarly, an evaluation tool that recognises the strengths of single-subject research in sport psychology (see Barker, McCarthy, Jones, & Moran, 2011), as well as the different quality criteria applied to these designs, would be welcomed. The tool was useful, however, for identifying common sources of bias across all of the studies, such as blinding and withdrawals and dropouts, and comparing the quality of the included studies.

Conclusions

This systematic literature review aimed to identify psychological determinants of endurance performance. Additional objectives were to evaluate the research practices of included studies, to suggest theoretical and applied implications, and to guide future research. Of the practical psychological interventions included, consistent support was found for using imagery, self-talk, and goal setting to enhance endurance performance. Psychological skills training could therefore benefit an endurance athlete. It is unclear, however, whether learning multiple psychological skills is more beneficial than learning one psychological skill. The results also demonstrated that mental fatigue undermines endurance performance, and verbal encouragement and head-to-head competition can have a beneficial effect. Consistent with the psychobiological model of endurance performance, interventions that affected perception of effort consistently affected endurance performance. Researchers are encouraged to compare different practical psychological interventions, to examine the effects of these interventions for athletes in competition, and to include a placebo control condition or an alternative control treatment. Researchers are also encouraged to explore additional psychological factors that could have a negative effect on endurance performance. Future research should measure psychological mediating variables and moderating variables.

Table 5

Quality Review and Evaluated Study Information – Practical Psychological Interventions

Quality criterion	Details	Barwood et al. (2015)	Barwood et al. (2008)	Blanchfield et al. (2014)	Burhans et al. (1988)	Caird et al. (1999)	Donohue et al. (2001)	Donohue et al. (2006)	Hamilton et al. (2007)	Jackson et al. (1979)	Lindsay et al. (2005)	A. Miller & Donohue (2003)	Morgan et al. (1983)	Okwumabua et al. (1983)	Patrick & Hrycaiko (1998)	Post et al. (2012)	Rushall & Shewchuk (1989)	Saintsing et al. (1988)	L. M. Scott et al. (1999)	Sheard & Golby (2006)	Tenenbaum et al. (1999)	Thelwell & Greenlees (2001)	Thelwell & Greenlees (2003)	Theodorakis et al. (1998)	Weinberg, Miller, et al. (2012)	Weinberg et al. (1984)
Study design	Label	M	S	S	S	M	W	S	W	M	W	S	S	M	W	W	W	M	W	W	–	W	W	M	W	M
Confounders	Identified	N	N	N	N	N	N	N	N	?	Y	Y	N	Y	N	N	N	N	N	Y	N	N	N	?	N	N
	Controlled									Y	N	N		N						N				N		
	Label	S	S	S	S	S	S	S	S	S	M	M	S	W	S	S	S	S	S	M	S	S	S	M	S	S
Blinding	Assessor									R	R		R							R						
	Participants	R	R	R	R					R						R		R		R	R					R
	Label	M	M	M	M	–	W	W	W	S	M	W	M	W	W	M	W	M	W	S	M	W	W	W	W	M
Data collection methods	Valid	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Reliable	R				R										R										
	Label	S	M	M	M	S	M	M	M	M	M	M	M	M	M	S	M	M	M	M	M	M	M	M	M	M
Withdrawals and dropouts	Reported	N	N	N	N	N	Y	N	Y	N	N	N	Y	N	N	Y	N	N	N	Y	N	Y	Y	Y	N	N
	Label	W	W	W	W	W	S	–	M	–	W	–	S	W	W	S	W	W	W	S	W	S	S	S	–	-
Intervention integrity	Consistency																			C						
	Contamination							C				C					C									
	Cointervention						C	C				C					C								C	
Overall label		M	M	M	M	M	W	M	W	M	W	M	S	W	W	M	W	M	W	M	–	W	W	M	W	M
Intervention adherence		N	½	Y	Y	Y	–	–	Y	–	Y	Y	N	Y	Y	Y	½	Y	Y	½	Y	Y	Y	Y	½	Y
Moderators		N	N	N	Y	N	N	N	–	Y	–	Y	N	N	–	–	N	N	–	N	Y	–	–	N	N	N
Possible psychological mediators		Y	Y	Y	Y	–	N	N	N	N	Y	N	Y	N	N	N	N	N	N	Y	–	N	N	N	N	Y
Targeted		Y	N	Y	N						Y		N							½						N
Placebo control		Y	N	N	N	–	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	–	N	N	N	N	N
Social validity / satisfaction		N	½	N	?	N	Y	Y	–	–	Y	Y	–	N	Y	Y	½	N	Y	Y	–	Y	Y	–	Y	–

Note. W = "weak" quality label; M = "moderate" quality label; S = "strong" quality label; Y = yes; N = no; ? = unclear; R = "Yes, reported in manuscript" (left blank when "no" or "not reported"); ½ = somewhat; – = not applicable to the evaluated study; C = concern identified relating to intervention integrity (left blank when concern not identified).

Table 6

Quality Review and Evaluated Study Information – Additional Psychological Determinants

Quality criterion	Details	Bath et al. (2012)	Blanchfield et al. (2014) Experiment 1	Blanchfield et al. (2014) Experiment 2	Bubb et al. (1985) Study 1	Bubb et al. (1985) Study 2	Chitwood et al. (1997)	Corbett et al. (2012)	Franks & Myers (1984) Study 1	Higgs (1972)	Hodgins et al. (2006)	Hulleman et al. (2007)	MacMahon et al. (2014)	Marcora et al. (2009)	M. Miller (1993)	Moffatt et al. (1994)	Pageaux et al. (2014)	Peveler & Green (2010)	Viru et al. (2010)	Wagstaff (2014)	E. L. Williams et al. (2015)	Wilmore (1968)
Study design	Label	M	S	S	M	M	S	M	S	W	S	M	S	S	S	S	S	W	S	S	M	M
Confounders	Identified	N	N	N	?	?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	Label	S	S	S	M	M	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Blinding	Assessor						R							R	?							
	Participants	R	R	R					R		R	R	R	R	?		R		R	R	R	
	Label	M	M	M	W	W	M	W	M	W	M	M	M	S	M	W	M	W	M	M	M	W
Data collection methods	Valid	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Reliable							R				R						R				R
	Label	M	M	M	M	M	M	S	M	M	M	S	M	M	M	M	M	S	M	M	M	S
Intervention integrity	Consistency								C							C			C			
	Contamination																					
	Cointervention																					
Overall quality	Label	M	M	M	M	M	M	M	M	W	M	M	M	S	M	M	M	W	M	M	M	M
Possible psychological mediators		Y	Y	Y	Y	Y	N	N	Y	N	Y	N	Y	Y	–	Y	Y	Y	N	Y	Y	N
Moderators		N	N	–	Y	Y	Y	N	Y	Y	N	N	N	N	Y	Y	N	N	N	N	N	N

Note. W = "weak" quality label; M = "moderate" quality label; S = "strong" quality label; Y = yes; N = no; R = "yes, reported in manuscript" (left blank when "no" or "not reported"); ? = unclear; – = not applicable to the evaluated study; C = concern identified relating to intervention integrity (left blank when concern not identified)

Chapter 3

Psychological Demands Experienced by Recreational Endurance Athletes

Alister McCormick, Carla Meijen, and Samuele Marcora

Endurance Research Group, School of Sport & Exercise Sciences, University of Kent, Medway Building, Chatham Maritime, Kent, ME4 4AG, United Kingdom

Aim of Chapter 3

The main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance. The thesis had three main research aims. Chapter 3 addressed the second research aim of the thesis, which was to inform the design of performance-enhancement psychological interventions for endurance sports. Specifically, Chapter 3 aimed to increase understanding of the psychological demands that are commonly experienced by endurance athletes so that performance-enhancement psychological interventions for endurance sports could target these demands. Although professional practice guidelines recommend that psychological skills training interventions target the demands of the sport to optimise their efficacy, Chapter 2 (systematic review) highlighted that few practical psychological interventions were designed specifically for the psychological demands of endurance sports. The psychological demands identified in the present chapter informed the content of the motivational self-talk intervention delivered to ultramarathon runners in Chapter 5.

Abstract

This study aimed to identify psychological demands that are commonly experienced by endurance athletes so that these demands could inform the design of performance-enhancement psychological interventions for endurance sports. Focus group interviews were conducted with 30 recreational endurance athletes of various sports (running, cycling, and triathlon), distances, and competitive levels to explore the psychological demands of training, competition preparation, and competition participation. An inductive thematic analysis was used to identify psychological demands that were experienced across sports, distances, and competitive levels. Seven themes captured demands that were commonly experienced away from the competitive environment (time investment and lifestyle sacrifices, commitment to training sessions, concerns about optimising training, and exercise sensations during training), preceding an event (pre-event stressors), or during an event (exercise sensations, optimising pacing, and remaining focused despite adversity). Interventions that help endurance athletes to cope with these psychological demands could encourage desirable outcomes relating to both performance in endurance sports and wellbeing. Experimental research examining the efficacy of such interventions is encouraged.

Introduction

The primary purpose of this study was to increase understanding of the psychological demands commonly encountered by endurance athletes, in order to inform the design of performance-enhancement psychological interventions for endurance sports. Sport psychology professional practice guidelines (Birrer & Morgan, 2010; Simons, 2012; Taylor, 1995) encourage practitioners who are designing a psychological performance-enhancement intervention to target the psychological demands of the sport, in order to optimise the efficacy of the intervention. Although the prominent psychological demands experienced in specific endurance events vary (Dosil, 2006; Kellmann et al., 2006; Taylor & Kress, 2006), there may be demands that are commonly experienced across various endurance sports, competitive distances, and competitive levels. Research examining the efficacy of interventions at enhancing endurance performance could target these common demands, which would provide an evidence base for practitioners working with endurance athletes who compete in various endurance events. In other words, efficacious interventions that target common psychological demands could have a wide application.

Psychological demands could be compared to stressors in transactional theories of stress. Transactional theories in sport psychology, such as cognitive-motivational-relational (CMR) theory (Lazarus, 1999, 2000), propose that stress is "an ongoing process that involves individuals transacting with their environment, making appraisals of the situations they find themselves in, and endeavouring to cope with any issues that might arise" (Fletcher et al., 2006, p. 329). From a transactional perspective, *stressors* refer to encountered environmental demands, namely events, situations, and conditions (Fletcher et al., 2006). How an athlete appraises stressors, and how well they cope with them, can influence an athlete's emotions, concentration, motivation, and ultimately their sport performance (Lazarus, 2000). Research has demonstrated that athletes encounter a wide range of stressors (Sarkar & Fletcher, 2014). These stressors can be broadly categorised as being associated with competitive performance (referred to as "competitive stressors"), the sport organisation that athletes operate within (referred to as "organisational stressors"), and personal life events outside of sport (referred to as "personal stressors"). Competitive stressors include preparation, injuries, pressure to perform well, underperformance in competition, performance expectations, self-presentation, and rivalry. Organisational stressors include leadership and personnel issues, cultural and team issues, logistical and environmental issues, and performance and personal issues. Personal stressors include the work–life interface, family issues, and the death of a significant other (Arnold & Fletcher, 2012; Sarkar & Fletcher, 2014). Some stressors, such as pressure to perform well, are experienced by most samples of athletes (McKay et al., 2008; Noblet & Gifford, 2002; Thelwell et al., 2007). Other stressors, however, are more prominent in certain samples of athletes, such as certain types of sport (McKay et al., 2008), competitive levels (Fletcher et al., 2012), and playing positions (Thelwell et al., 2007).

Research has illuminated psychological demands experienced during specific endurance events. For example, swimmers who successfully completed the English Channel crossing reported that staying focused during the middle of the swim was particularly challenging because of physical and thermal pain, sea-life encounters (e.g., jellyfish stings), and loneliness (Hollander & Acevedo, 2000). In addition, ultramarathon runners reported that muscle cramping and injuries, gastrointestinal problems, and thoughts about quitting were key stressors during a 125-kilometre ultramarathon (Holt et al., 2014). Furthermore, exertion pain is suggested to be the biggest psychological demand for elite-level cyclists (Kress & Statler, 2007), and "hitting the wall" is a demand facing recreational marathon runners (Buman et al., 2008). Anecdotally, endurance athletes in various sports and distances also experience some common psychological demands (e.g., Taylor, 1995; Tuffey, 2000). For example, Tuffey (2000) argued that endurance athletes experience three broad psychological demands: 1) long and repetitive training sessions that can undermine motivation; 2) pain, discomfort, and fatigue experienced in training and competition; and 3) preparation for competition, including planning for pain and discomfort and developing and committing to a race plan. There is a lack of research, however, that has included athletes of different endurance sports, distances, or competitive levels and examined demands that are commonly encountered by these athletes.

Research to date has illuminated demands experienced by athletes competing in a wide range of sports, including specific endurance events. Some demands are commonly encountered across sports, playing positions, and competitive levels, but others are particularly prominent in certain samples of athletes. To date, no studies have included athletes of different endurance sports, distances, or competitive levels and examined whether any psychological demands commonly affect endurance athletes. The aim of the present study was to increase understanding of the psychological demands commonly encountered by endurance athletes, in order to inform the design of performance-enhancement psychological interventions for endurance sports. Research demonstrating the efficacy of psychological interventions that target common demands would provide an evidence base that practitioners working with endurance athletes could consider. This study also aimed to draw attention to common psychological demands that relate to wellbeing instead of performance, such as sport enjoyment, to support holistic psychology practice.

Methods

Research Philosophy

The primary researcher held a pragmatic research philosophy and attempted to provide useful data for researchers and practitioners interested in performance enhancement in endurance sports (Giacobbi, Poczwardowski, & Hager, 2005). Throughout the study, data collection and analysis strategies were chosen based on their suitability for identifying psychological demands that are commonly experienced across various endurance sports, distances, and competitive levels (Onwuegbuzie & Leech, 2005).

Research Design

Focus group interviews were used to collect data. Focus groups offer a tool to identify areas of consensus and disagreement between participants' experiences, and they can generate rich data by capitalising on group interaction such as discussion, debate, exchange of anecdotes, and use of humour (Kitzinger, 2006; Patton, 2002).

Participants

Maximum variation sampling (Patton, 2002) was chosen, and participants of different sports, distances, competitive levels, ages, and genders were included. The researchers assumed that they would identify unique themes in each of the focus groups that would shed light on psychological demands experienced by specific groups. Nevertheless, the researchers were primarily interested in common psychological demands identified in spite of this variation that could represent central, shared experiences that characterise participation in endurance sports (Patton, 2002).

Participants were 30 British, recreational endurance athletes. Interviews were conducted with the following groups: runners (n = 10) who competed at distances ranging from 800 metres to half marathons, including cross country; cyclists (n = 6) who competed in time trials, road races, or both; triathletes who competed at distances ranging from sprint to long distance (n = 10); and triathletes who predominantly competed in long-distance events (n = 4). These sports and distances are consistent with the definition of endurance performance that was used to guide this thesis ("performance during whole-body, dynamic exercise that involves continuous effort and lasts for 75 seconds or longer”). Information on participant characteristics were collected using a questionnaire (Appendix F, p. 283). Participants estimated, using a fixed range of values, the number of events they had participated in during the previous year (median = 6-10) and in total (median = 21-50). Focus group composition and participant characteristics are summarised in Table 7.

Table 7

Overview of Participant Characteristics

Focus group	Gender	Age	Competitive level	Yearly training (weeks)	Weekly training (hours)	Years competing at the sport	Years competing at main distance
Runners	m = 7, f = 3	21 ± 3	n = 4, r = 4, u = 2	50 ± 4	9 ± 2	7 ± 4	4 ± 3
Triathletes	m = 7, f = 3	41 ± 11	a = 6, l = 4	48 ± 4	13 ± 6	10 ± 7	6 ± 3
Cyclists	m = 6	50 ± 17	a = 1, l = 5	48 ± 3	11 ± 2	10 ± 13	9 ± 13
LD triathletes	m = 4	45 ± 4	v = 4	47 ± 5	13 ± 7	5 ± 2	3 ± 2
Overall	m = 24, f = 6	37 ± 15		48 ± 4	11 ± 5	8 ± 8	5 ± 7

Note. a = age-group national or international; f = female; l = local; LD = long-distance; m = male; n = national; r = regional; u = university; v = pursuing personal bests in various countries; ± = mean ± standard deviation.

Procedure

Ethical approval was granted by the department ethics committee. Gatekeepers (e.g., coaches, committee contacts) at endurance sport clubs in South East England were then contacted by email, and interviews were organised when there was sufficient interest from suitable athletes in a similar geographic location. Three gatekeepers hosted a focus group with members of their club, and a fourth focus group (three of four participants were from the same club) was held at the researchers’ university. Using pre-existing groups had the advantages that participants were comfortable talking to one another, they related to each other’s contributions, and they offered different perspectives on specific examples (Kitzinger, 1994). Each focus group involved athletes from one sport so that shared familiarity of the sport would facilitate in-depth discussion. The primary researcher, who had experience conducting qualitative research and had not competed in an endurance sport, facilitated all focus groups. Before the first focus group, the facilitator conducted a pilot focus group with recreational runners to practise using the interview guide, to test the relevance of questions, and to gain feedback on facilitation skills from the second author. The questions were well received and judged by the researchers to be appropriate for further use. Before each focus group, the facilitator reflected in writing (Appendix G, p. 285) on topics of discussion that were expected based on familiarity with sport psychology literature and personal assumptions, themes they hoped would emerge (e.g., pain and discomfort are demands in competition, boredom is a demand in training) and would not emerge (notably, anxiety plays a key role in performance), and questions they perceived to be more important or more interesting (e.g., "I am more interested in the demands faced during competition. I therefore risk rushing through the questions about the demands experienced before competition"). The main purpose of this activity was to raise awareness of assumptions and expectations about the demands experienced by particular groups of endurance athletes and the researcher's own biases so that, during the focus group, the facilitator could self-question choices that could influence the results (e.g., choice of probing questions, decision to move on to a new question). At the focus groups, chairs were set up to form a circle, and refreshments were available throughout. Participants provided informed consent before each focus group (see Appendix H, p. 293, for the participant information sheet and consent form). Focus groups lasted between 85 and 115 minutes, and they were audio recorded.

Interview Guide

A semi-structured interview guide (Appendix I, p. 297) was prepared following the guidance of Patton (2002). The facilitator began each focus group by describing what a focus group involves, and he encouraged participants to talk to one another, ask questions, exchange anecdotes, and comment on others' experiences and points of view

(Kitzinger, 2006). The facilitator then set ground rules (e.g., no interrupting) and introduced the topic. Specifically, the researcher explained that he was interested in learning about the mental demands that endurance athletes experience before and during competition. A demand was defined as a typical aspect of the sport that makes the sport difficult. The researcher also specified that he wished to talk about the thoughts and feelings that the participants experienced when training, preparing for competition, and competing. Participants were encouraged to think about specific, relevant experiences that they could remember well before answering each question. To familiarise participants with the focus group format and to help them feel relaxed, the first question asked participants to describe what they enjoy about competing (Patton, 2002). The remainder of the focus group was dedicated to four main questions. These questions addressed psychological demands of training ("What do you feel are the mental demands that you face, if there are any, when you are training for your sport?"), psychological demands experienced during the build-up to a competition, psychological demands experienced during a competition, and mental characteristics needed to excel. The facilitator also asked whether pre-competition demands change as a competition draws closer and whether demands vary during different stages of a race. Participants were encouraged to talk about experiences that endurance athletes might take for granted. The facilitator used detail, clarification, and elaboration probes, compared and contrasted responses, summarised content, and asked for examples throughout (Patton, 2002). The facilitator also invited less-vocal participants to contribute, and he moved on from each question when probing no longer led to the discussion of new material. Before concluding, participants were given an opportunity to discuss experiences that were not covered.

Data Analysis

The interviews were transcribed verbatim by the primary researcher, producing 213 pages of double-spaced text. During transcription, care was taken to include features that could influence data interpretation, such as laughter and pauses in speech. The transcripts were analysed in NVivo using a thematic analysis that involved six phases: familiarisation with data; generating initial codes; searching for themes; reviewing themes; defining and naming themes; and producing the report (Braun & Clarke, 2006) (see Table 8).

Table 8 (reproduced with permission from Braun & Clarke, 2006, p. 87)
Phases of Thematic Analysis

Phase	Description of the process
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

A number of decisions were made about how to analyse the data (see Braun & Clarke, 2006). Each theme was judged to capture "something important about the data in relation to the research question, and represents some level of *patterned* [original emphasis] response or meaning within the data set" (Braun & Clarke, 2006, p. 82). An inductive (i.e., data-driven) thematic analysis was chosen, and themes were identified in the explicit or surface meanings of the data, so that the themes reflected participants' accounts of experienced psychological demands. As this study is interested in psychological demands that are experienced across endurance sports, themes were identified across (rather than within) focus groups, and the themes provide an overall description of the demands faced by the endurance athletes (rather than focusing on a small number of themes). The second author, who studied all transcriptions, acted as a "Devil's advocate" after phases 3 and 4, critically challenging the primary researcher's interpretation of the data (Krane, Andersen, & Strean, 1997). Critical discussion led to the addition of one theme (concerns about optimising training) and refinement of the other six themes. The researchers reflected on the internal homogeneity (meaningful coherence within a theme) and external heterogeneity (clear and distinct differences between themes) of shortlisted themes throughout the refinement of themes and sub-themes to avoid overlapping theme content (Patton, 2002).

Results

Seven themes (summarised in Table 9, p. 106) captured psychological demands that were commonly experienced across endurance sports, distances, and competitive levels. These demands were commonly experienced away from the competitive environment (time investment and lifestyle sacrifices, commitment to training sessions, concerns about optimising training, and exercise sensations during training), preceding an event (pre-event stressors), or during an event (exercise sensations, optimising pacing, and remaining focused despite adversity). To help the reader judge the relative prominence of each theme across and within focus groups, Table 9 states the number of participants in each focus group whose verbal contributions were coded within each theme (note, however, that non-verbal behaviours could not be coded, and "uh huhs" could not be attributed to specific participants). The themes are presented in the order that they might be experienced during the build-up to and during an event; training-related themes are presented first, followed by preparation and competition themes, respectively. Quotes are used to capture the essence of each theme.

Table 9

Overview of Themes and Sub-Themes

Themes	Sub-themes	Essence of the theme/ sub-theme	Participants coded within the theme/sub-theme
Time investment and lifestyle sacrifices	Time investment to participate	The endurance athlete struggles to find time to train.	C = 3, R = 2, LDT = 3, T = 7 Subtheme total = 15
	Sacrifices made for the sport	The athlete and their family make sacrifices so that the athlete can participate in the sport.	C = 3, R = 6, LDT = 3, T = 4 Subtheme total = 16 Theme total = 21
Commitment to training sessions		Remaining committed to training is difficult, particularly when training alone in bad weather.	C = 5, R = 8, LDT = 2, T = 10 Theme total = 25
Concerns about optimising training		The athlete is concerned about doing insufficient, inappropriate, or substandard training.	C = 0, R = 3, LDT = 1, T = 5 Theme total = 9
Pre-event stressors	Logistical stressors and worries	Pre-event logistics are stressful, and the athlete worries that something might go wrong before the event start.	C = 0, R = 0, LDT = 3, T = 7 Subtheme total = 10
	Something goes wrong	Something goes wrong before the event start, and it has a negative effect on the athlete’s mental state.	C = 4, R = 1, LDT = 1, T = 0 Subtheme total = 6 Theme total = 15
Exercise sensations	Exercise sensations during training	Training is hard work and painful.	C = 6, R = 5, LDT = 0, T = 2 Subtheme total = 13
	Exercise sensations during an event	The athlete experiences exertion, pain, fatigue, and discomfort during the event.	C = 3, R = 5, LDT = 4, T = 7 Subtheme total = 19 Theme total = 23
Optimising pacing during an event	Pushing yet pacing	The athlete finds it difficult to judge how hard they can push their self during an event.	C = 0, R = 2, LDT = 4, T = 8 Subtheme total = 14
	Effect of other competitors on pacing	The athlete has to make pacing decisions based on the behaviour of other performers.	C = 4, R = 5, LDT = 0, T = 3 Subtheme total = 12 Theme total = 21
Remaining focused despite adversity during an event		The athlete finds it difficult to re-focus and remain motivated after encountering a stressor.	C = 5, R = 6, LDT = 4, T = 7 Theme total = 22

Note. C = Cyclists (out of 6); R = Runners (out of 10); LDT = Long-distance triathletes (out of 4); T = Triathletes (out of 10).

Time Investment and Lifestyle Sacrifices

Training for endurance events required a substantial time investment from the endurance athletes. As they also had family, employment, university, and social commitments, athletes in each focus group struggled to find the time to train. Some athletes found this stressful, and they described experiencing negatively-toned emotions such as frustration and anxiety.

> Long-distance triathlete (LDT) 1: Especially if you've got, like you say, I've got no kids, but I've got a wife and trying to keep her happy and not be training all the time, working, you know, it's kind of, trying to juggle that, it can be mentally straining in itself. It's just trying to juggle everything so you're doing enough training and then the frustration of, "I don't feel as if I've done enough training" and then the worry, "I need to do more", but physically I can't do anymore because I've not got any time.
>
> Triathlete (T) 1: The half-Irons and the long, long distances that you have to spend hours and hours and hours on a bike, you can't get away from spending a minimum of spending six hours on a bike at a time just because your race will involve it and then you have to do that probably twice a week on each discipline that you're doing, so you've got six training sessions for every little rest and that impacts. (His wife) T2's done practically no events this year because it was kind of my turn to do a race, whereas next year, I don't know quite what we're going to do because we're both racing. Anyone else want some children?

The athletes described the sacrifices that they made so that they could train and compete, which included other sports, hobbies, employment opportunities, social opportunities, and spending time with family. The athletes were also aware of the sacrifices that their families made for them to train and compete, and they recognised that they needed their family's support. Some athletes were willing to prioritise training and competing over other opportunities and commitments, and they planned their days around training and competing. Four athletes with families even stated that athletes need to be selfish to excel in their sport. Nevertheless, the sacrifices made by family were sometimes a source of negatively-toned emotions such as guilt.

> Cyclist (C) 1: And I feel, to a point sometimes, a bit, a bit guilty, it's come up before about, sort of the amount of time I'm away from my wife, she's very understanding, all the rest of it, but there is that sort of that nagging "Maybe I shouldn't be doing this, I should be at home doing some painting or I should be going out with her".

Commitment to Training Sessions

Athletes in each focus group reported a lack of motivation to start a training session and a willingness to miss training sessions. This was particularly the case when they were training alone and when the weather was cold or wet. Although numerous reasons were given for this lack of motivation, such as not having an incentive like an upcoming event, a particularly common reason was that the training was not enjoyable. Making arrangements to train with others (e.g., squad training, organising to train with friends) helped the athletes commit to attending training sessions and to work hard in those training sessions.

> Runner (R) dialogue:
>
> > R1: Once you start, it's ok. It's actually getting up and out of the house.
> >
> > R2: On my own, that's definitely the case. If I'm going down to train with people, then it's not an issue, not at all.
> >
> > R3: For example, like for the Tuesday and Thursday sessions, a lot of us obviously enjoy them because we go down and there's a big group there and we all do the session together, but probably if all of us had to do the

Tuesday and Thursday sessions on our own, half of us probably wouldn't do them.

T3: I have to focus on the thing that I'm weakest at (cycling) because... that's the biggest chunk in half-Ironman, that's the most amount of time (pause) but, like T2, I couldn't go out and do it on my own, I'd need company (laughs)... It's like when people say, "Oh, it's fun". It's not fun to me. I have to make myself.

T4: I'm the sort that if I've made arrangements to go out with somebody, we'll go. But if I'm on my own and it's pouring down with rain, I probably won't go.

Concerns About Optimising Training

Runners and triathletes described concerns about the quantity, appropriateness, or standard of their training. This theme manifested differently across the focus groups. Dialogue between three runners, who frequently trained together in a group, suggested that they were critical of substandard performances in single training sessions and focused on these performances rather than their longer-term progress, they compared their training performances to other runners despite differences in training objectives, and they worried about taking rest days because they did not want to lose fitness

R4: We're just training, it's not a race, but sometimes we're treating it like a race and we're thinking, "I should have beaten him today, I should have beaten him"... you don't know what other people are doing in between the sessions, like, you know, they might have had a rest day the day before, you might have done eight miles or something.

R5: I know if I have a rubbish session, I'll be like, "Lost it, that's it", when really you've just had an off day.

R4: I'll text (the coach) like after a rest day and like panic that I shouldn't have done that, like I'm going to lose something from it... for a couple of hours, I'll think, "Oh shit, I've lost it, I'm going to lose a bit of fitness from that" because I regret doing it, but in actual fact it's probably helped me rather than sort of made it worse.

The triathletes, on the other hand, described examples where they lacked confidence that they were doing the right training or worried about getting the right balance between the three disciplines.

Triathlete dialogue:

T5: You think, "Oh, am I concentrating on that sport too much?"

T6: Or am I getting enough miles on the bike or

T7: Well, it's juggling, isn't it. (T6: Yeah) You're concentrating more on one, you're losing off the other, don't you.

T6: Exactly.

T8: I think triathlon is funny in that sense, really, because you're never, never as good as you can be in any individual aspect.

Exercise Sensations During Training

The athletes described experiences of pain and exertion during training. These experiences were particularly prominent among the runners and cyclists, who trained at high intensity. The athletes recognised that they need to push through discomfort to achieve the physiological adaptation necessary to improve their performance.

C1: It's incredibly painful for me. When I go out with certain people (laughing) and we do a hard session, I mean it's maximal for me, when you're riding with people who can stretch you, it is absolutely flat out, I'm putting myself into pain zones that I've never been in to before and would never do but, but for the fact that I'm trying to push the performance envelope.

T2: You know that you've got to push your body beyond what is comfortable in order for it to adapt— it's the principle of training. If you just sit there at a speed that's comfortable in whatever discipline, you're not going to adapt, you're not going to improve, so you know you've got to get over that mental barrier, somehow going beyond what's physically comfortable.

Pre-Event Stressors

Cyclists and triathletes described substantial event preparation, which included packing their bag and equipment, checking their bike, and learning the event route. They also described difficult logistical aspects encountered on the day of an event, including waking up early, driving to an event with closed roads and congestion, finding parking, registering at the event, and setting their bike in the swim-cycle transition and memorising its location. As a consequence, some of the athletes reported feeling stressed before the event, and they worried that something might go wrong.

T9: I get quite stressed out. With triathlon, it's not like turning up at a running race with your trainers and your shorts and t-shirt and off you go— there's so many logistical and mechanical aspects.

The athletes also described unexpected disruptions to these pre-event activities, which included running late to the event and forgetting a piece of equipment. These disruptions led to the athlete feeling agitated, annoyed, or distracted.

C2: If I forget one thing, it might be something minor that doesn't make a lot of difference but it ruins me mentally… It leaves me flustered, yeah. And I want to be on the start line with a clear head, and it doesn't give me that. I'm fretting.

Optimising Pacing During an Event

The athletes wanted to pace themselves optimally to finish an event, to achieve a time, or to place well in the standings. The athletes balanced pushing themselves to their limit with avoiding premature exhaustion. Some of the athletes reported feeling uncertain about their pace and questioned whether they were pushing hard enough. This demand appeared particularly relevant to athletes who participated in longer races, especially triathlons.

> T1: I always, yeah worry, "Am I going fast enough?" because it feels a bit too comfortable.
>
> T8: I think that's the difficult part, saying "How fast can I really go and still just about make it across the finishing line?"
>
> LDT2: I find it mentally quite challenging balancing the three disciplines because, you know, you turn up to the run, you've overcooked it on the bike, guess what, Armageddon. You overcook it on the swim, Armageddon... There's this line, you know, if you push it by 2%, you're going to get away with it... it's going to get you that PB (personal best), it's going to get you in that top whatever number it is that you're looking to achieve. You push it, you know, that 1% over, dog-doo, you're dead.

Competitive athletes who raced head-to-head described the tactical pacing decisions that they made in relation to other performers. They had to decide whether to adjust their pace to catch, shake off, or fall behind a competitor, or whether to trust their own pace.

> R6: So like if somebody comes past you in a race, it's having the confidence that you will still beat them in the end, which happened to me in a couple of races where someone's come past and I've managed to still get them at the end. You've got the choice of whether to believe when they go past you, if you're going to let them go, stay with them, if you think that you are quicker than them, still believe in yourself.

T9: A Swiss guy came past and I clocked his number off. I thought, “Yeah, he’s in my wave and age group, I’ve got to go with this guy... Stuff how I feel, if I want to win this race, I can’t have him in front of me” so I just went with him.

Tactical decisions were particularly important to road-race cyclists who raced for finishing positions and not times. Indeed, Cyclist 3 described racing as a “moving game of chess” because of the constantly-changing tactical elements of racing. The cyclists reported constantly monitoring performance cues (e.g., positions of other cyclists, environmental and road conditions), and they reacted to the behaviours of other cyclists.

C4: You need to understand where everybody else is, not only in terms of their location around you, but where they are in terms of what they’ve got left, how much of a threat are they still, how much have they got left in the tank, what sort of riders are they? You’re coming up, you know, last Sunday in a break of four, and you find yourself assessing each rider, you know, how are they going to sprint? Yeah. Shall hit them with a long one? Shall I leave it late and go really hard?

Exercise Sensations During an Event

A demand consistently reported across focus groups was the exertion, pain, fatigue, and discomfort experienced during events. Words such as “pain”, “hurt”, and “suffering” captured a range of unpleasant exercise-induced sensations that typically became more prominent as the event progressed and were greatest at the end. The athletes described a desire to stop or slow down, and they described unhelpful self-talk that was persuading them to not continue.

Runner dialogue:

Facilitator: If you take out male and female, if you take out teenager versus someone in their twenties, if you take out the distance, what do you think are the typical demands of running that will always be there?

R7: Well, you're going through physical Hell and you've got to finish it as well as you can…

R5: It's probably one of the only sports where, the goal of it is to push yourself through as much physical pain as you can, and that's basically the goal… push yourself to your maximum. That's it.

R8: Getting to the bell (in a 1,500-metre race) and then realising that you've still just got to do this 400 metres to make it, I think, in my mind, everything's hurting, everything's in pain, but somebody's saying "It's only 400 metres, it's only 400 metres", but somebody else is saying "You're dead, you're not going to be able to make it"— you're always fighting against your head in a race.

LDT3: If you're not thinking about anything (i.e., distracting yourself), all you're going to think about is your feet hurt, your ankles hurt (LDT4: Yeah. My knee hurts), everything hurts, you just think about all the bits that hurt, all the reasons why it's madness to keep on putting one foot in front of the other, "You should just stop".

Remaining Focused Despite Adversity During an Event

The athletes reported a wide range of stressors that were encountered during endurance events. These included unfavourable environmental conditions, being overtaken, substandard performance, collisions, bike punctures, nutritional mistakes, and dropping food or a water bottle. Athletes in each focus group reported occasions where these stressors had a detrimental effect on their mental state. Specifically, the athletes often reported responding with unconstructive self-talk statements and experiencing negatively-toned emotions such as discouragement and frustration. Further, they described difficulty re-focusing on their performance and remaining motivated.

Cyclist dialogue:

> C3: Head winds can have an even worse effect because all of sudden you cannot go faster, and you forget the fact that it's the same for everyone else as well, you know, it's not just you...
>
> C2: It still feels very personal at the time…
>
> C3: Especially on the time trial, you're convincing yourself that you're the only one feeling like that in these conditions, be it rainy and you're going slow, or your disk wheel's getting hit by sidewind, you think that's not happening to anyone else and it's just you, and you're looking down at your dock, "I'm 30 seconds off what I should be", you know, "disaster".

C4: When you're really going well, you look good, you know, and it's all coming together and the adrenaline's flowing, you know, ppheeww, you're on fire. When things start to go wrong, that's when it's a very difficult mental position to be in, I think, and that's the hardest thing to try to learn, how to overcome that "Oh shit, what a terrible day this is".

LDT4: I had my PB up by probably half an hour on a good course and missing one bottle, just literally, just flipped out my hand, scuppered the lot (laughing), took it out completely. And that's it, you've then got to go for the rest of the race thinking, (numerous laughing) "I've buggered up all that training", and now a year's worth of training, six months of dedicated commitment, (laughing) and it's all gone to pot.

Discussion

This study aimed to increase understanding of the psychological demands commonly encountered by endurance athletes, particularly to inform the design of performance-enhancement psychological interventions for endurance sports. Seven themes captured demands that were experienced away from the competitive environment (time investment and lifestyle sacrifices, commitment to training sessions, concerns about optimising training, and exercise sensations during training), preceding an event (pre-event stressors), or during an event (exercise sensations, optimising pacing, and remaining focused despite adversity). These demands were perceived to affect motivation and concentration and therefore have implications for performance. The demands were also perceived to affect outcomes related to wellbeing, such as the emotions experienced before, during, and after events. Interventions that help endurance athletes to cope with these psychological demands could therefore encourage desirable outcomes related to both performance in endurance sports and wellbeing.

The results of this study draw attention to stressors that are commonly encountered by recreational endurance athletes. The endurance athletes reported a range of competitive stressors (e.g., being overtaken), as well as personal stressors related to time demands and lifestyle sacrifices and organisational stressors related to pre-race logistics. Previous research has demonstrated that some stressors are commonly experienced across most samples of athletes (e.g., McKay et al., 2008), whereas others are particularly prominent in specific samples of athletes, such as certain types of sport (McKay et al., 2008) and competitive levels (Fletcher et al., 2012). Endurance athletes in the present study reported some demands that are commonly experienced across sports, whereas other demands appear particularly prominent in endurance sports. For example, the time investment and lifestyle sacrifices, the demand of optimising pacing, and the experienced exercise sensations appear to characterise performing in endurance sports at the recreational level. In contrast, some themes, such as pre-event stressors and remaining focused despite adversity, reflect demands that are experienced in a range of sports (e.g., Dugdale, Eklund, & Gordon, 2002; Mellalieu, Neil, Hanton, & Fletcher, 2009). For example, athletes in many sports commonly encounter stressors during competitions that can undermine their motivation and concentration, such as making a mistake, poor officiating, or conceding to the opposition at crucial times (Dugdale et al., 2002). Independent of whether the themes highlight demands that are unique to endurance sports, these demands are often experienced by endurance athletes and could therefore inform the design of interventions for endurance sports.

A demand that is prominent among recreational endurance athletes relates to time demands and lifestyle sacrifices. Participants estimated that they trained for an average of 11 hours each week (Table 7, p. 100). This is a substantial time investment for people who compete recreationally, rather than professionally. A substantial training investment is necessary, however, because participating and excelling in endurance sports requires a high level of aerobic fitness. Other studies have similarly highlighted that ultramarathon runners (Simpson et al., 2014) and masters cyclists (Appleby & Dieffenbach, 2016) dedicate a substantial amount of time to training, which can come at the expense of other activities such as socialising with friends. Although balancing competing time demands, making personal sacrifices, and knowing that family have made sacrifices are recognised stressors for elite-level athletes in other sports (Gould, Jackson, & Finch, 1993; McKay et al., 2008; Noblet & Gifford, 2002; Scanlan, Stein, & Ravizza, 1991), the substantial time investment and sacrifices associated with participation in endurance sports are unusual for recreational populations of athletes.

A second demand particularly prominent in endurance sports relates to exercise sensations (exertion, pain, fatigue, and discomfort) experienced during training sessions and events. Although these sensations have distinct qualities and neurophysiological mechanisms (e.g., Marcora, 2009; Mauger, 2014), they are grouped together because the experience of these exercise-induced sensations reflects how demanding or challenging it is to continue exercising. Other studies have also portrayed these sensations as demanding during endurance exercise (Brick, MacIntyre, & Campbell, 2015; Crust, Nesti, & Bond, 2010; Hollander & Acevedo, 2000; Holt et al., 2014; Kress & Statler, 2007; Samson et al., 2015; J. M. Schumacher et al., 2016; Simpson, Post, & Tashman, 2013; Simpson et al., 2014). This broad demand manifests differently in different endurance events. For example, injury-related pain, such as hurting feet and knees, is a prominent exercise sensation for athletes competing over longer distances such as ultramarathons (Holt et al., 2014), and intense exercise-induced muscle pain is a prominent exercise sensation for athletes who train and compete at high intensity (Kress & Statler, 2007). Unpleasant sensations indicate that an athlete is pushing their self, and participants recognised that they need to persevere to achieve physiological adaptation from training or a desired outcome from an event. Psychological skills training strategies that help athletes to persevere despite high levels of perceived effort (Blanchfield, Hardy, de Morree, et al., 2014) and pain (Whitmarsh & Alderman, 1993) in training and in events could help endurance athletes to achieve these desired outcomes.

In the present study, athletes reported difficulties remaining committed to training sessions, and the exercise sensations experienced during training could be a contributing factor. Research demonstrates that exercise becomes less pleasurable when the intensity exceeds the lactate and ventilatory thresholds, and exercise becomes unpleasant when the intensity reaches maximal oxygen consumption (Ekkekakis et al., 2011). The lack of pleasure experienced from exercising in an endurance activity, combined with cold and wet weather and a lack of social interactions when training alone, may mean that some training sessions are less enjoyable and, as a consequence, the athletes may be less committed to these training sessions (L. Williams, 2013).

An additional prominent demand related to pacing. Some athletes felt uncertain about whether they should increase their pace, or they worried that they were not pushing hard enough. These self-reports of pacing uncertainty may be attributed to the athletes' inability to accurately predict how their perceived effort would increase during the rest of the event. The endurance athletes might therefore have been cautious in how hard they pushed their selves so that they avoided premature exhaustion (Marcora & Bosio, 2007; Marcora, 2010). Competitive athletes who raced head-to-head also described pacing decisions that were influenced by the behaviours of competitors. For example, they reported occasions where they had to decide whether to trust their own pace or adopt the pace of a faster competitor, which involves the risk of premature exhaustion. These head-to-head pacing decisions are difficult for endurance athletes, because the performance environment is constantly changing, there are a lot of relevant cues to consider, athletes do not know the current physiological capacity of their competitors, and decisions often need to be made quickly and under pressure (Renfree, Martin, Micklewright, & St Clair Gibson, 2014). Research that helps endurance athletes to use the most relevant cues to make fast decisions that optimise their performance has been encouraged (Renfree et al., 2014).

Stressors that were encountered away from the competitive environment (e.g., finding time to train), before an event (e.g., arriving late), and during an event (e.g., unfavourable weather) were associated with self-reports of feeling stressed and negatively-toned emotions such as frustration, guilt, anxiety, and discouragement. Encountered stressors and associated negatively-toned emotions were also reported to affect the athletes' motivation and concentration. The effects of stressors on endurance athletes' emotions, motivation, and concentration can be explained by CMR theory (Lazarus, 1999, 2000). According to CMR theory, the type and intensity of emotions that an athlete experiences are determined by how they appraise the significance of their relationship with their environment (i.e., stressors) to their personal wellbeing (Martinent & Ferrand, 2015; Uphill & Jones, 2007). Endurance athletes' self-reports of feeling stressed and negatively-toned emotions indicate that they appraised what was happening as putting something important at stake, such as the opportunity to participate in a desired event, a personal best time, or a position in the standings (primary appraisal). The self-reports also indicate that the athletes did not believe that they could cope (secondary appraisal). Consistent with CMR theory, experiencing negatively-toned emotions led to the athletes experiencing reduced motivation for training and competition and focusing on task-irrelevant cues (e.g., an argument with family) during training and competition. In addition to appraisals, the emotions that an athlete experiences are determined by a coping process that operates throughout an emotional encounter. Endurance athletes use a broad selection of coping strategies to regulate their emotions before and during performance (e.g., Stanley et al., 2012), and the effectiveness of an endurance athlete's coping strategies could influence their emotions, motivation, concentration, and ultimately their performance.

Intervention Design and Applied Implications

This study aimed to inform the design of performance-enhancement psychological interventions for endurance sports. In Chapter 2 (systematic review), a range of psychological interventions were shown to enhance endurance performance, but few of these interventions appeared to target the demands of the particular endurance sport or the demands of endurance events in general. The potential benefits of targeting the demands reported in this study include performance enhancement, but they also extend to valuable outcomes related to wellbeing, such as enjoyment and satisfaction. Many sport psychology practitioners aspire to help athletes to achieve these wellbeing-related outcomes (e.g., Brady & Maynard, 2010). Experimental research examining the effects of interventions that target some of the highlighted psychological demands is encouraged.

In the context of transactional theories of stress, such as CMR theory, efforts to manage the stress process in athletes can occur at three levels (primary, secondary, tertiary). Primary interventions aim to eliminate or at least reduce the quantity, frequency, or intensity of stressors, secondary interventions aim to modify athletes' psychological responses to stressors, and tertiary interventions aim to minimise the damaging consequences of stressors by helping athletes to cope with reduced performance or wellbeing that result from negative psychological, physical, and behavioural responses to stressors (Fletcher et al., 2006). Applied suggestions are offered for each level.

For recreational endurance athletes, many competitions are mass-participation events, and the findings of this study indicate that logistical and environmental organisational stressors (Arnold & Fletcher, 2012) related to travel (e.g., congestion, closed roads), rules and regulations (e.g., required arrival times), and distractions (e.g., locating toilets) are prominent. As an example of a primary intervention, practitioners could provide guidance on preparing to attend an upcoming endurance event through online media and pre-event workshops. For example, endurance athletes could reduce pre-event stressors by creating a packing checklist, researching anticipated road and car-park congestion, and preparing a timetable to arrive at the event early. Indeed, there are computer and phone applications available that help with packing for an endurance event (e.g., http://triathlon.racechecklist.com).

As an example of a secondary intervention, endurance athletes could use implementation intentions, or "if-then plans", to prepare for stressors that could occur before or during an endurance event. Specifically, athletes could identify detrimental inner states (e.g., unconstructive thoughts or emotions) and obstacles that they might encounter (e.g., a tyre puncture), and plan cognitive (e.g., motivational self-talk statements, adjustment of goals) or behavioural (e.g., repairing a puncture, change of pace) responses (Achtziger, Gollwitzer, & Sheeran, 2008). Endurance athletes could also visualise implementing these responses, or they could actually practise them (e.g., taking goggles on and off during a swim). Preparing and practising implementation intentions could help athletes respond quickly and constructively to stressors so that they can continue pursuing their performance goals (Achtziger et al., 2008). Few experimental studies (Achtziger et al., 2008; Stern, Cole, Gollwitzer, Oettingen, & Balcetis, 2013) have examined the efficacy of using implementation intentions to enhance sport performance. For experimental research, problems encountered by endurance athletes, such as being overtaken by another athlete or losing time to an uncontrollable factor (e.g., random puncture time penalties) could be simulated in controlled laboratory conditions.

Recreational endurance athletes may experience performance decrements and reduced wellbeing because of stressors such as injury or having limited time to train due to family and work commitments. Tertiary interventions can be used to help athletes to cope with these performance decrements and reduced wellbeing. As an example, sport psychologists may be present at an endurance event as part of a "psyching team". Psyching teams provide psychological support for endurance events such as marathons using online media, workshops, written handouts, dinner speeches, and brief conversations with athletes before, during, and after the endurance event. As part of the structure of a psyching team, sport psychologists may be present at the end of the event in locations such as the medical tent, and can help athletes to manage thwarted performance expectations (Meijen, Day, & Hays, 2016).

Finally, endurance athletes dedicate a substantial amount of time to training, even at the recreational level. It can be difficult for endurance athletes to find time to train because of family, work, and other commitments, and endurance athletes and their families make sacrifices so that the athlete can train and compete. When designing an intervention, practitioners and researchers should consider the restricted time that endurance athletes have available. Interventions that can be accessed at flexible times and from flexible locations, such as PST that is delivered online (Weinberg, Neff, & Jurica, 2012), could be particularly valuable for this population. Practitioners should also be aware that demands outside of sport, such as time and family stressors, can affect an endurance athlete's experiences during training and events. Practitioners working with an endurance athlete are therefore encouraged to adopt a holistic approach to service delivery and to consider the interplay between the athlete's different life domains (e.g., Friesen & Orlick, 2010).

Limitations

This study aimed to identify psychological demands that are commonly experienced by endurance athletes. Covering a broad range of demands related to training, competition preparation, and competition participation was useful for informing psychological interventions for endurance sports, but it meant that individual demands were not explored in depth. Future research could build on these findings by focusing on a narrow range of demands. In addition, this study focused on the demands experienced by endurance athletes, and it did not examine the full stress process including appraisals, emotions, and coping (cf. Miles et al., 2016; Neil et al., 2016). Future research that is informed by a transactional theory of stress, such as CMR theory, could shed greater light on the complete stress process in endurance athletes. The presented data indicates that research informed by transactional theories could inform the application of psychology in endurance sports to support valuable outcomes related to both performance and wellbeing. Finally, competitive level influences the demands that athletes encounter (Fletcher et al., 2012). Participants in the present study competed recreationally rather than professionally, and some of the themes will reflect this. For example, having a full-time job contributed to participants having little time to train. Similar research might therefore examine the prominent psychological demands experienced by professional endurance athletes.

Conclusions

This study aimed to increase understanding of the psychological demands commonly encountered by endurance athletes, in order to inform the design of performance-enhancement psychological interventions for endurance sports. Identified themes shed light on psychological demands that are commonly encountered away from the competitive environment (time investment and lifestyle sacrifices, commitment to training sessions, concerns about optimising training, and exercise sensations during training), preceding an endurance event (pre-event stressors), and during an event (exercise sensations, optimising pacing, and remaining focused despite adversity). Interventions that help endurance athletes to cope with these psychological demands could encourage desirable outcomes related to both performance in endurance sports and wellbeing. Experimental research examining the efficacy of such interventions is encouraged.

Chapter 4

Application of the Facial Feedback Hypothesis to Endurance Performance – Does Frowning Modulate Perception of Effort?

Alister McCormick[1], Carla Meijen[1],
Benjamin Pageaux[2], and Samuele Marcora[1]

[1] Endurance Research Group, School of Sport & Exercise Sciences, University of Kent, Medway Building, Chatham Maritime, Kent, ME4 4AG, United Kingdom

[2] CAPS UMR1093, INSERM, Univ. Bourgogne-Franche Comté, F-21000 Dijon, France

Aim of Chapter 4

The main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance. The thesis had three main research aims. Like Chapter 3 (qualitative study), Chapter 4 addressed the second aim of the thesis, which was to inform the design of performance-enhancement psychological interventions for endurance sports. Chapter 2 (systematic literature review) highlighted a paucity of theoretically-informed research on the psychological determinants of endurance performance. Chapter 4 applied psychological theory to examine a novel method of influencing endurance performance. Specifically, Chapter 4 examined the relationship between frowning and perception of effort. Although research indicates that people frown more when they perceive high levels of effort, research on the facial feedback hypothesis suggests that frowning might also modulate perception of effort. In other words, frowning (or not frowning) could influence how strenuous exercise feels to an athlete. If frowning does modulate perception of effort, then interventions aimed at reducing frowning could offer a novel, psychologically-informed method of enhancing endurance performance.

Abstract

Research on the facial feedback hypothesis suggests that afferent feedback from the bilateral corrugator supercilii (CS) muscles when frowning may modulate perception of effort during endurance performance. Applying predictions of the facial feedback hypothesis and the psychobiological model of endurance performance, this study examined whether intentionally frowning throughout a cycling time-to-exhaustion test increased perception of effort and, consequently, reduced time to exhaustion. In addition, this study examined the effects of intentionally frowning on affective states experienced during performance and after exhaustion. Ten recreational endurance athletes performed cycling time-to-exhaustion tests in three conditions that were completed in a randomised and counterbalanced order. For a frowning condition and a matched-workload control condition, participants were taught to use electromyography (EMG) root mean square (RMS) feedback to maintain the contraction of specified muscles. In the frowning condition, participants maintained at least 10% of their maximum EMG RMS for the CS muscles throughout the time-to-exhaustion test. In the matched-workload control condition, participants maintained at least 10% of their maximum EMG RMS for the thenar muscles of the thumb. In a no-intervention control condition, participants were not required to contract the CS or thenar muscles. Perception of effort and exercise-related affect were measured during performance, and positive and negative affective states were measured before and after. The results demonstrated that intentionally frowning did not affect perception of effort, affective states experienced during or after performance, or time to exhaustion. These findings suggest that frowning may not modulate perception of effort during endurance performance. Although additional research using different methods would offer greater clarity, the findings suggest that interventions targeting the expression of a frown would seem unlikely to offer an efficacious method of enhancing endurance performance.

Introduction

> A man (sic) may be absorbed in the deepest thought, and his brow will remain smooth until he encounters some obstacle in his train of reasoning, or is interrupted by some disturbance, and then a frown passes like a shadow over his brow… frowning is not the expression of simple reflection, however profound, or of attention, however close, but of something difficult or displeasing encountered in a train of thought or action. (Darwin, 1913, pp. 221-222)

The corrugator supercilii (CS) muscles are located medially on the eyebrow ridge (see Figure 1, p. 129). When a person frowns, the CS muscles draw the brows together and downward, producing vertical furrows between the brows (Tassinary, Cacioppo, & Vanman, 2007). As observed by Charles Darwin, people frown when they perceive a cognitive task or physical task to be difficult. Indeed, electromyography (EMG) studies have demonstrated that the activity of the CS muscles increase with the effort required by cognitive tasks (Cacioppo, Petty, & Morris, 1985; van Boxtel & Jessurun, 1993; Waterink & van Boxtel, 1994) and physical tasks (de Morree & Marcora, 2010, 2012; Huang et al., 2014). For example, van Boxtel and Jessurun (1993) demonstrated that CS muscle EMG amplitude was greater during an information-processing task than during rest periods, and EMG amplitude increased with the task load. Further, CS muscle EMG activity positively correlates with task difficulty and ratings of perceived exertion (RPE) during leg-extension tasks (de Morree & Marcora, 2010) and incremental-workload cycling (Huang et al., 2014), it can differentiate heavy- and severe-intensity constant-workload cycling (de Morree & Marcora, 2012), and it positively correlates with exercise duration and RPE during severe-intensity, constant-workload cycling (de Morree & Marcora, 2012).[1] Indeed, the role of frowning in expressing effort during physical tasks is captured by a validated pictorial RPE scale that represents perceived effort using faces that are frowning to varying degrees (Huang

& Chiou, 2013) (see Figure 2). Although frowning evidently expresses effort in cognitive and physical tasks, research on the facial feedback hypothesis suggests that frowning might also modulate perception of effort. In other words, frowning might affect how effortful a task feels to the performer.

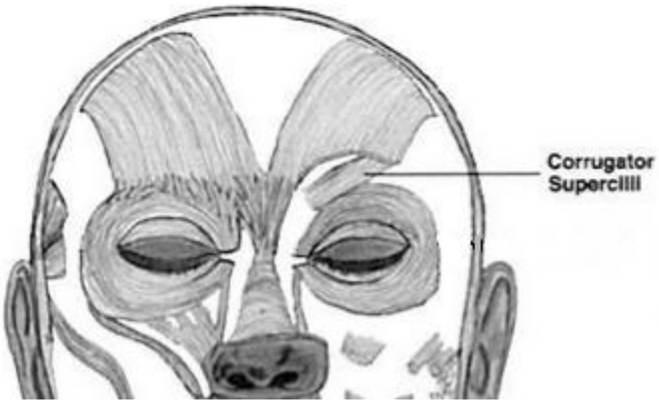

Figure 1. Location of the left corrugator supercilii muscle (reproduced with permission from Goodmurphy & Ovalle, 1999, p. 2).

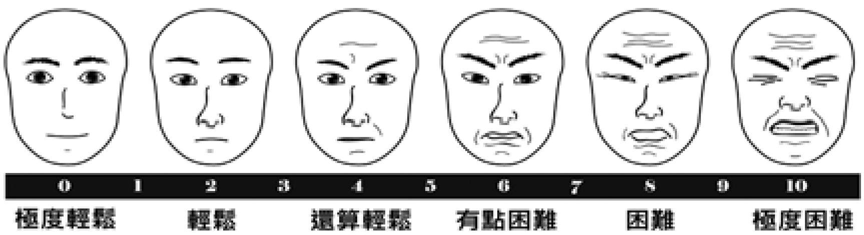

Figure 2. The facial pictorial rating of perceived exertion scale (reproduced with permission from Huang & Chiou, 2013, p. 127), which demonstrates the role of frowning in expressing effort during physical tasks.

The facial feedback hypothesis proposes that afferent feedback from facial musculature affects an individual's emotional state (Niedenthal et al., 2005). In other words, facial expressions can play a causal role in the experience of emotions. One version of the facial feedback hypothesis, the sufficiency hypothesis, proposes that performing a facial expression is sufficient to elicit a congruent emotional experience. For example, mood states become more negative when people lower their eyebrows by contracting the CS muscles (Lewis, 2012, Experiment 1). A second version, the modulation hypothesis, proposes that congruent facial expressions modulate (amplify or soften) emotional experiences that are elicited by external stimuli (Davis et al., 2009; Niedenthal et al., 2005). The modulation hypothesis has received considerable research support. For example, in a particularly influential study, people rated cartoons as funnier when they held a pen in their teeth—a task that subtly facilitates muscular activity involved in a smile—than people who held a pen in their mouths or non-dominant hand (Strack et al., 1988). Similarly, subtly encouraging people to contract the CS muscles to furrow their brow, which produces a facial pattern associated with sadness, led to them feeling sadder while they viewed aversive photographs (Larsen et al., 1992). Furthermore, people were more surprised by unusual facts when they were raising their eyebrows, and they judged repulsive odours to be more unpleasant when they were wrinkling their noses (Lewis, 2012, Experiments 2 and 3). In addition to emotional states, facial expressions can modulate what Stepper and Strack (1993) termed *non-emotional feelings*, such as perceived effort and pain. For example, a memory-recollection task was perceived as more effortful when frowning compared to smiling (Stepper & Strack, 1993, Study 2), and the reported aversiveness of low- and medium-intensity electric shocks was lower when maintaining a straight face (Lanzetta et al., 1976, Experiment 1). Together, research on the facial feedback hypothesis demonstrates that the role of facial musculature is not limited to expressing feeling states; facial musculature can also modulate feeling states.

As facial expressions can modulate how a person feels, it is plausible that changing facial expression during exercise could influence exercise-induced feeling states such as perception of effort and exercise-related affect. Indeed, one of few studies that has applied research on the facial feedback hypothesis to exercise found that exercisers reported more positive exercise-related affect—that is, greater pleasure—and lower perception of effort when smiling compared to frowning, both at rest and during moderate-intensity cycling (Philippen et al., 2012). It was unclear, however, whether the changes in exercise-related affect and perception of effort were caused by the presence of a smile or the absence of a frown. An additional study also demonstrated that wearing sunglasses while running, which might have reduced the need to squint and therefore CS muscle afferent feedback, reduced perception of effort during three-mile runs (Laguna & Dobbert, 2002). The main aim of the present study was to determine whether frowning modulates perception of effort during endurance performance.

If frowning modulates perception of effort during endurance performance, then interventions targeting frowning could offer a novel method of enhancing endurance performance. According to the psychobiological model of endurance performance, perception of effort is one of the main determinants of endurance performance (Marcora et al., 2008; Marcora, 2010a). The psychobiological model predicts that any intervention that decreases perception of effort will enhance endurance performance, and any intervention that increases perception of effort will detrimentally affect endurance performance (Marcora et al., 2008). Supporting this prediction, motivational self-talk (Blanchfield, Hardy, de Morree, et al., 2014), psychological skills training (Barwood et al., 2008), and dissociative cognitive strategies (Morgan et al., 1984) appear to reduce perception of effort and they enhance endurance performance, whereas mental fatigue (Marcora et al., 2009) and emotion suppression (Wagstaff, 2014) increase perception of effort and detrimentally affect endurance performance. The present study examined whether frowning during endurance performance increases perception of effort and, as predicted by the psychobiological model, detrimentally affects endurance performance.

Although the CS muscles contribute to the expression of effort, the CS muscles also contribute to the expression of negatively-toned emotions such as anger, sadness, and fear (e.g., Heckmann et al., 2003). Further, as described above, there is evidence that afferent feedback from the CS muscles modulates the experience of these emotions (Larsen et al., 1992; Lewis, 2012). There is also evidence that afferent feedback from the CS muscles modulates enduring mood states. Indeed, a single treatment of botulinum toxin (Botox), which temporarily paralyses facial muscles in the brow region and prevents afferent feedback from them, has been shown to reduce patients' symptoms of major depression (Wollmer et al., 2012). In addition to examining the effect of frowning on perception of effort, the present study therefore examined the effect of frowning on affective states experienced during and after endurance performance.

When people are experiencing high amounts of effort, they tend to frown more. A substantial volume of research on the facial feedback hypothesis, however, suggests that frowning may also modulate perception of effort. Applying predictions of the psychobiological model of endurance performance and the facial feedback hypothesis, the present study investigated whether frowning affects perception of effort and performance in a cycling time-to-exhaustion test. Specifically, it was hypothesised that intentionally frowning would increase perception of effort and reduce time to exhaustion. As the CS muscles also modulate the experience of negatively-toned emotions and mood states, the present study also examined the effects of frowning on affective states experienced during performance and after exhaustion.

Methods

Participants

Participants were five male (age = 43.6 ± 5.7 years, height = 179 ± 5 cm, weight = 79.2 ± 7.5 kg, peak power output [PPO] = 388 ± 22 Watts, maximum oxygen uptake

[$\dot{V}O_{2max}$] = 56.0 ± 4.4 ml·kg^{-1}·min^{-1}) and five female (age = 34.8 ± 4.5 years, height = 164 ± 7 cm, weight = 63.2 ± 12.7 kg, PPO = 263 ± 39 Watts, $\dot{V}O_{2max}$ = 47.8 ± 7.2 ml·kg^{-1}·min^{-1}) recreational runners, cyclists, and triathletes recruited from local clubs. Participants exercised for 10.5 ± 4.3 hours on 5.3 ± 0.9 days per week, and they were healthy and free from injury. Information on participant characteristics were collected using a questionnaire (Appendix J, p. 302). An apriori statistical power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) calculated that 10 participants would be necessary to detect a medium effect size (Cohen's f = 0.25) with an α error probably of .05 and 90% power, assuming a correlation of 0.90 among repeated measures (based on comparable data from other studies, e.g., Blanchfield, Hardy, de Morree, et al., 2014) and a nonsphericity correction (ϵ) value of 0.88 (based on initial data).

Participants were asked to follow instructions throughout their involvement in the study (maintain current diet, maintain current aerobic exercise regimen, and wear similar clothing to each laboratory visit), during the 24 hours preceding a laboratory visit (drink 40ml of water per kilogram of body weight, sleep for at least seven hours, refrain from alcohol consumption, and avoid strenuous exercise), and during the two hours preceding a laboratory visit (eat a light meal two hours before, and avoid caffeine and nicotine). A checklist was used to determine whether participants had complied with these instructions, as well as whether they had taken any medication or had an illness, injury, or infection (Appendix K, p. 303). Participants were naïve to the study's aims and hypotheses, and they were informed that the study investigated "whether intentionally contracting particular muscles on the body or face influences heart rate data during exhaustive exercise". The purpose of the study was revealed after data collection had finished for all participants.

Design

A randomised, controlled, crossover experimental design was used to compare (within-subjects) the effects of frowning with control conditions. Participants visited the laboratory on five occasions (visit 1 = incremental test, visit 2 = familiarisation, visits 3-5 = experimental trials), and there were at least 48 hours between visits. During visits 3-5, participants performed a cycling time-to-exhaustion test in an experimental condition or one of two control conditions. In the experimental condition ("frowning condition"), participants maintained at least 10% of their maximum EMG root mean square (RMS) of the CS muscles throughout the time-to-exhaustion test. In the matched-workload control condition ("thumb-press condition"), participants maintained at least 10% of their maximum EMG RMS of the thenar muscles of the thumb. This condition controlled for the mental (e.g., dual-task demands, distraction) and physical demands of maintaining a muscle contraction *per se*. In the no-intervention control condition, participants were not required to contract the CS or thenar muscles. The order of trials was randomised and counterbalanced (www.randomization.com).

Visit 1 – Incremental Test

Ethical approval was granted by the department ethics committee before commencement of data collection. In advance of their first visit, participants completed a health questionnaire (Appendix L, p. 306). Upon arrival at this visit, participants provided written informed consent (Appendix M, p. 313), and they were weighed and measured. Consistent with department guidelines for maximal exercise testing, the resting blood pressure of male participants between the age of 45 and 50 was checked. Participants then performed a ramp incremental cycling test to establish their $\dot{V}O_{2max}$, gas exchange threshold (GET), and PPO. Cycling tests during all visits were performed on an electromagnetically-braked cycle ergometer (Corival 906900, Lode, Groningen, Netherlands) with consistent saddle height. For all cycling tests, participants were asked to remain in the saddle, maintain a cadence between 60 and 100 rotations per minute (rpm), and offer their best performance. The cycle ergometer was set in hyperbolic mode so that power output was independent of cadence. The incremental test started with three minutes of cycling at 20 Watts, then the power output increased at a rate of 30 Watts per minute until participants stopped cycling or their cadence dropped below 60 rpm for five seconds despite strong verbal encouragement (Kelly, Vanhatalo, Wilkerson, Wylie, & Jones, 2013). Breath-by-breath pulmonary gas exchange data were collected continuously during the incremental test using a computerized metabolic gas analysis system (MetaLyzer 3BR2; Cortex, Leipzig, Germany) connected to an oro-nasal mask (V2 mask, Hans Rudolph, Shawnee, KS). The gas analysis system was calibrated prior to each incremental test in accordance with the manufacturer's guidelines. The GET was determined by identifying the first disproportionate increase in CO_2 production ($\dot{V}CO_2$) from visual inspection of individual plots of $\dot{V}CO_2$ versus oxygen uptake ($\dot{V}O_2$), an increase in expired ventilation / $\dot{V}O_2$ with no increase in expired ventilation / $\dot{V}CO_2$, and an increase in end-tidal O_2 tension with no fall in end-tidal CO_2 tension (Kelly et al., 2013). $\dot{V}O_{2max}$ was the highest mean $\dot{V}O_2$ for any 10-second period.

Visit 2 – Familiarisation

Participants were familiarised with all experimental procedures. First, participants performed a cycling time-to-exhaustion test. Time-to-exhaustion tests are sensitive to the effects of interventions that affect endurance performance (Amann et al., 2008). Following three minutes of cycling at 20 Watts, participants cycled at a severe-intensity power output corresponding to 60% of the difference between the power output at the GET and the power output at $\dot{V}O_{2max}$ (72.8 ± 3.1% PPO). Two-thirds of the ramp rate (20 Watts) was deducted from the work rate at the GET and $\dot{V}O_{2max}$ to account for the mean lag time of $\dot{V}O_2$ during ramp exercise (Whipp, Davis, Torres, &

Wasserman, 1981). The ergometer handlebars were set vertically, and participants were instructed to hold the upper horizontal handlebar with their thumbs on top of the handlebar. A fan was positioned approximately one metre in front of the ergometer and was switched on throughout the time-to-exhaustion test, and a RPE Scale and a Feeling Scale were in full view throughout each time-to-exhaustion test (see Psychological Scales and Questionnaires section, p. 140). Performance time was the duration between starting the severe-intensity cycling and either stopping or being unable to maintain a cadence of at least 60 rpm for five consecutive seconds. The experimenter stood behind the participant, he did not converse or offer encouragement, and he told the participant if their cadence dropped below 60 rpm. Heart rate (Polar heart rate chest strap T31, Polar Electro Inc, New York, USA), cadence, RPE, and Feeling Scale values were recorded every minute during the time-to-exhaustion test. A fresh blood sample was collected from the tip of the index finger before the warm up and three minutes after exhaustion, and blood lactate concentration was measured using a calibrated device (Biosen C-Line, EKF Diagnostic, London, UK). The time lapsed was not displayed during the time-to-exhaustion test. Depending on performance time, the power output of the time-to-exhaustion test was adjusted for subsequent visits to increase the probability that the performance time would be close to 10 minutes. Ten minutes was chosen as the target duration because pilot data indicated that participants could maintain the muscle contractions for this duration without excessive discomfort, the workload of the two muscle-contraction tasks would be similar over this duration, and the frowning task would be efficacious at increasing CS muscle activity at this intensity.

Following the time-to-exhaustion test, participants practised the muscle-contraction tasks (see Muscle Contraction Interventions section, p. 138) for 10 minutes each while cycling at a self-selected, moderate-intensity power output. All participants were able to maintain the muscle contractions for this duration without excessive discomfort. Participants also practised using each of the psychological scales and questionnaires.

Visits 3 to 5 – Experimental and Control Conditions

Experimental trials were conducted in a private area of the laboratory without observers. They were organised for the same time of day, and there was an average of 6 ± 1 days between visits 3 and 5. Laboratory temperature (18.8 ± 0.5 °C), humidity (44.3 ± 4.3%), and atmospheric pressure (1006 ± 5 mb) were similar for each visit. During these visits, participants performed a cycling time-to-exhaustion test at 71.9 ± 2.6% PPO while contracting the CS muscles, while contracting the thenar muscles of the thumb, or without instructions to contract facial or thumb muscles (see Muscle Contraction Interventions section, p. 138). Before each time-to-exhaustion test, participants practised both muscle-contraction tasks for one minute while stationary on the ergometer. The order of practice tasks was consistent within-subjects, and it was randomised and counterbalanced between participants. Participants did not perform the assigned muscle-contraction task during the warm-up. EMG data were collected throughout all time-to-exhaustion tests. Participants did not receive feedback on their performance times until the study was completed. Performance motivation and confidence were measured before the time-to-exhaustion test, affective states were measured before and after the time-to-exhaustion test, and perceived intervention workload was measured after the time-to-exhaustion test (see Psychological Scales and Questionnaires section, p. 140, for additional details; see Appendix N, p. 318, for a copy of the questionnaire). The experimental protocol is summarised in Figure 3 (p. 138). An example protocol checklist used by the researcher is presented in Appendix O (p. 325).

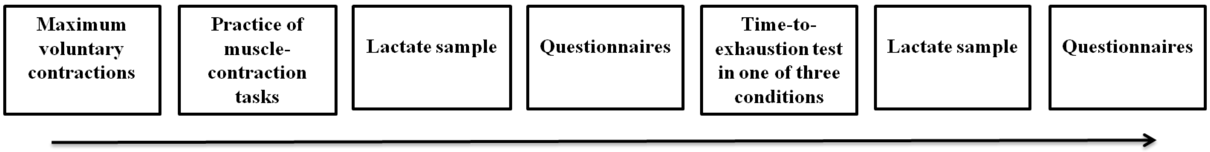

Figure 3. Summary of the experimental protocol.

Muscle Contraction Interventions

EMG RMS feedback was used to deliver the muscle-contraction interventions. First, bipolar surface electrodes were attached to the bilateral CS muscles (Neuroline 72000-S/25; Ambu Inc., Klstykke, Denmark) and the thenar muscles (NeuroPlus A10043, VERMED, Bellows Falls, VT) of the participant’s dominant hand (nine of 10 participants were right-handed). Before electrode placement, all placement areas were shaved if necessary, cleaned with an alcohol swab, and dried with a paper towel. One pair of electrodes was attached to each of CS muscles. The first electrode was placed directly above the endocanthion and superior to the eyebrow. The second electrode was placed lateral from the first electrode along an imaginary line extending from the glabellar to the ipsilateral superciliary arch of the frontal bone so that the line formed a 60-degree angle with the facial midline (Tassinary, Cacioppo, & Geen, 1989). For the thenar muscles, the electrodes were placed over the thenar eminence, along an imaginary line from the thumb to the wrist. This group of muscles contract during opposition of the thumb (Biel, 2005). The reference electrode was positioned on the head of the ulna, and the electrode wires were taped to the arm to reduce movement artefacts. The EMG signals were transmitted and amplified by a multichannel EMG wireless device (BioNomadix, Biopac Systems Inc, Goleta, USA) with a bandwidth frequency ranging from 10 Hz to 500 Hz (gain = 2000, acquisition sampling rate = 2 kHz), then displayed on a computer and recorded for offline analysis using specialised software (Acq*Knowledge*, Biopac Systems Inc, Goleta, USA).

After the electrodes were attached, participants performed three maximum voluntary contractions (MVCs) of the bilateral CS muscles and three MVCs of the thenar muscles with strong verbal encouragement. The duration of each MVC was three seconds. For the CS muscles, participants were instructed to push against the ergometer handlebars, to imagine they were pushing an unmovable object, and to push their brows together and downwards as firmly as possible. For the thenar muscles, participants were instructed to hold the upper horizontal handlebar of the ergometer with their thumbs on top of the handlebar and to push the thumb of their dominant hand downwards against the handlebar as firmly as possible. For each CS muscle and thenar muscle contraction, the EMG RMS was averaged for the 0.5 seconds surrounding the EMG RMS peak value. The highest of the three CS muscle contractions and the highest of the three thumb contractions were recorded. These two values were divided by 10 to set the EMG RMS value corresponding to 10% of the maximum EMG RMS.

For the muscle-contraction tasks, participants were required to maintain at least 10% of their maximum EMG RMS while cycling. Participants were instructed to maintain the muscle contraction from the onset of the time-to-exhaustion test, for as much of the test duration as possible. Participants were also instructed to keep their eyes open in the frowning condition, and they were only required to press the handlebar with their dominant hand in the thumb-press condition. A computer displayed live EMG data (waveform sampling rate = 31.25 Hz). The researcher monitored the live EMG data and said the word “up” when the EMG RMS fell below 10% of the participant’s maximum EMG RMS (frowning condition = 1.56 ± 1.88 “ups” per trial, thumb-press condition = 1.89 ± 1.83 “ups” per trial). The computer screen was hidden from participants’ view by a large partition to lessen the cognitive demands of the muscle-contraction tasks. The experimental set-up is illustrated in Figure 4 (p. 140).

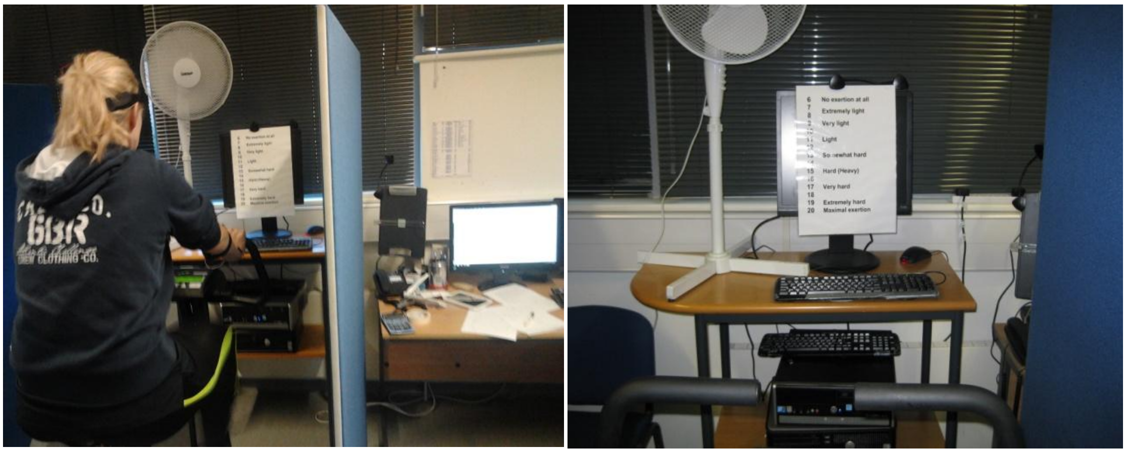

Figure 4. Experimental set-up from the perspective of the researcher (left photograph) and from the perspective of the participant (right photograph).

Psychological Scales and Questionnaires

Performance motivation and confidence. Participants rated their level of agreement with two statements that measured their performance motivation ("I want to give it everything I have got in the time-to-exhaustion test") and confidence ("I can cope with the exertion, pain, fatigue, and discomfort experienced during the time-to-exhaustion test") on a Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree") before they started the time-to-exhaustion test.

Ratings of perceived exertion. Before each cycling test, participants were given standardised, written instructions for rating their overall perception of effort using the 6-20 RPE Scale (G. A. Borg, 1998). These instructions (Appendix P, p. 328) included a definition of perception of effort ("how effortful, heavy, and strenuous the exercise feels", Marcora, 2010a), an explanation of the nature and use of the scale, definitions of scale anchors (e.g., "15 – It is hard and tiring, but continuing is not terribly difficult."), and a statement that there are no right and wrong answers. Once participants had read the instructions, the experimenter reinforced the content of the instructions and answered questions (Noble & Robertson, 1996a). Participants practised using the scale during the incremental test and familiarisation time-to-exhaustion test.

Feeling Scale. In-task exercise-related affect was measured using the Feeling Scale (Hardy & Rejeski, 1989). The Feeling Scale is a bipolar scale of pleasure and displeasure that ranges from -5 (“Very bad”) to +5 (“Very good”) (Appendix Q, p. 331). Participants practised using the scale during the familiarisation time-to-exhaustion test.

Positive and Negative Affect Scale (PANAS). Positive and negative affect were measured using the PANAS (Watson, Clark, & Tellegen, 1988). The PANAS is comprised of 10 positive affect items (e.g., excited) and 10 negative affect items (e.g., distressed). Responders rate the extent to which they are feeling each item at the present moment on a five-point scale, ranging from 1 (“Very Slightly or Not at All”) to 5 (“Extremely”).

Brunel Mood Scale (BRUMS). Congruent with the frowning intervention, a brow that is lowered and drawn together helps to signify anger (Ekman, 2004). Anger was measured using the BRUMS (Terry, Lane, Lane, & Keohane, 1999), because the PANAS does not include an anger subscale. The BRUMS contains 24 items divided into six subscales (anger, confusion, depression, fatigue, tension, and vigor). For each item, responders rate how they feel on a five-point scale, ranging from 0 (“not at all”) to 4 (“extremely”). Although the anger subscale was of particular interest, the data for the additional five subscales are presented in Table A4 (Appendix R, p. 332).

Intervention workload. The subjective workload of each muscle-contraction task was measured using the NASA Task Load Index (NASA-TLX) (Hart, 2006). Each participant rated six workload subscales (mental demand, physical demand, temporal demand, performance, effort, and frustration) on a 20-point scale. The scale anchors were “low” and “high”, with the exception of the performance subscale (“good” and “poor”). An overall workload score was calculated by weighing each rating by the participant’s perception of its relative importance. Participants determined the weights when completing the NASA-TLX for their first muscle-contraction task, and the same weights were applied to their ratings for their second muscle-contraction task. Participant instructions were modified from the paper-and-pencil version instruction manual (retrieved from http://humansystems.arc.nasa.gov/groups/tlx/paperpencil.html) to increase their relevance to the specific tasks (Appendix S, p. 333).

Post-study questionnaire. To probe whether participants guessed the study's aims and hypotheses, participants were asked to describe what they thought was the purpose of the study, as well as what they expected the results to show (Appendix T, p. 338).

Data Analysis

The assumptions of all statistical tests were checked, and the chosen statistical tests were judged to be appropriate for the analysed data. Friedman tests of differences among repeated measures were used to determine if there were differences in performance motivation or performance confidence. One-way, repeated-measures ANOVAs were used to determine if there were differences in time to exhaustion, changes in positive affect and negative affect from pre- to post-performance, and post-performance blood lactate concentration. One-way, repeated-measures ANOVAs or Friedman tests of differences (depending on whether participant scores were normally distributed) were used to compare changes in BRUMS subscales from pre- to post-performance. A two-tailed, paired-samples *t*-test was used to determine if there was a difference in the workload experienced during the frowning and thumb-contraction tasks. Two-way, repeated-measures ANOVAs (3 x 5) were used to determine if the interventions affected EMG, RPE, Feeling Scale, heart rate, and cadence values over time. Five isotime values (60 seconds, 40% of isotime, 60% of isotime, 80% of isotime, and 100% of isotime) were used to compare EMG, RPE, Feeling Scale, heart rate, and cadence values at equivalent time points between conditions. The cycling duration of each participant's shortest time-to-exhaustion test corresponded to 100% isotime for that participant. This duration was then multiplied by 0.4, 0.6, and 0.8 to determine 40%, 60%, and 80% of isotime for each participant. RPE, Feeling Scale, heart rate, and cadence values that were recorded after one minute and after the minute nearest (within 30 seconds) to 40%, 60%, 80%, and 100% isotime were analysed. The CS muscle and thumb EMG data were filtered with a zero-lag, band-pass, fourth-order Butterworth filter (cutoff frequencies = 20 and 400 Hz), and the EMG RMS values were averaged between the five isotime time points (0-60 seconds, 60 seconds to 40% isotime, 40-60% isotime, 60-80% isotime, and 80-100% isotime) and expressed relative to the maximum EMG RMS that preceded the trial.[2] For ANOVAs, the Greenhouse–Geisser correction was used when the sphericity assumption was violated.

For all analyses, statistical significance was set at $p < .05$ (two tailed). Partial eta squared (η_p^2) effect sizes are presented for ANOVAs. Small, moderate, and large effect size anchors are 0.01, 0.06, and 0.14, respectively (Cohen, 1988). Glass's delta (Δ) effect size values were calculated (Hojat & Xu, 2004) for the effects of the muscle-contraction interventions on time to exhaustion. Small, moderate, and large effect size anchors are 0.20, 0.50, and 0.80, respectively (Cohen, 1988). Mean and standard deviation values are reported as measures of central tendency and variation for continuous data, and median and interquartile range (IQR) values are reported for ordinal data.

Results

Naïvety to Aims and Hypotheses

Attempts to conceal the study aims and hypotheses were successful. No participants correctly determined that the frowning intervention was the independent variable of primary interest and that the thumb-press intervention was a control. Eight of 10 participants correctly determined that time to exhaustion, rather than heart rate, was the dependent variable of primary interest. One participant predicted that, at the group level, both muscle-contraction tasks would have a detrimental effect on performance, two participants predicted that both muscle-contraction tasks would have a beneficial effect on performance, and one participant predicted that the frowning task (only) would have a beneficial effect on performance.

Performance Motivation and Confidence

Motivation values were identical across conditions (out of 5, median = 5.00, IQR = 4-5). Confidence values in the frowning (median = 4.50, IQR = 4-5), thumb-press (median = 4.50, IQR = 4-5), and no-intervention conditions (median = 5.00, IQR = 4-5) varied for one only participant, and the differences were not statistically significant, $\chi^2(2) = 2.00$, $p = .37$.

EMG Manipulation Check

The frowning and thumb-press interventions were efficacious at increasing the EMG activity of the CS and thenar muscles, respectively. As evident in Figure 5 (p. 145), CS muscle activity increased over time in all conditions, and EMG activity was greater in the frowning condition than the control conditions at all time points. The main effect of condition on CS muscle EMG activity was statistically significant, $F(1.21, 9.64) = 26.7$, $p < .001$, $\eta_p^2 = 0.77$. Pairwise comparisons (with Bonferroni adjustment) indicated that EMG activity was greater in the frowning condition compared to the thumb-press ($p = .004$) and no-intervention conditions ($p = .001$), but EMG activity did not significantly differ between the two control conditions ($p = 1.00$). The main effect of time on CS muscle EMG activity was also significant, $F(1.25, 10.0) = 12.8$, $p = .004$, $\eta_p^2 = 0.62$. There was not a significant interaction between time and condition, $F(1.98, 15.8) = 0.33$, $p = .72$, $\eta_p^2 = 0.039$.

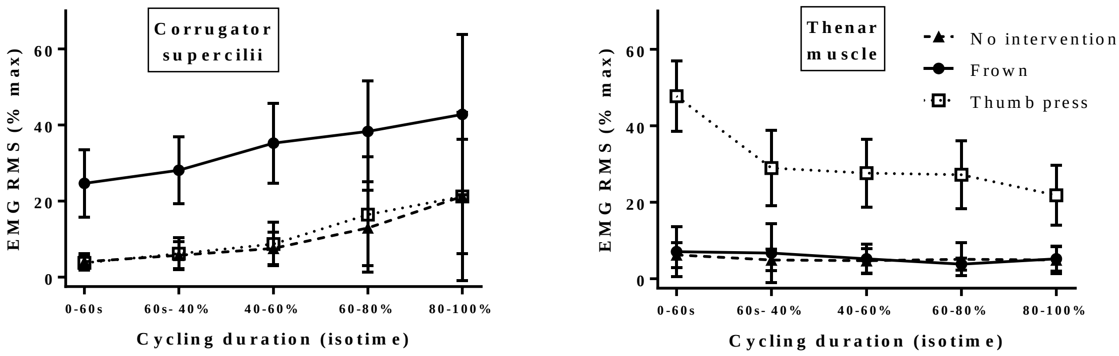

Figure 5. Mean ± standard deviation corrugator supercilii (left panel) and thenar muscle (right panel) EMG RMS (expressed relative to maximum EMG RMS) over time in the frowning, thumb-press, and no-intervention conditions.

As evident in Figure 5, thenar muscle activity was greater in the thumb-press condition than the frowning and no-intervention conditions at all time points, and EMG activity decreased over time in the thumb-press condition. The main effect of condition on thenar muscle EMG activity was statistically significant, $F(1.21, 8.47) = 70.0$, $p < .001$, $\eta_p^2 = 0.91$. Pairwise comparisons indicated that EMG activity was greater in the thumb-press condition compared to the frowning ($p < .001$) and no-intervention conditions ($p < .001$), but EMG activity did not significantly differ between the frowning and no-intervention conditions ($p = 1.00$). The main effect of time on thenar muscle activity was significant, $F(2.05, 14.3) = 19.3$, $p < .001$, $\eta_p^2 = 0.73$, and there was a significant interaction between time and condition, $F(2.26, 15.8) = 16.1$, $p < .001$, $\eta_p^2 = 0.70$. Follow-up one-way ANOVAs indicated that there was a main effect of time in the thumb-press condition, $F(4, 32) = 22.6$, $p < .001$, $\eta_p^2 = 0.74$, but not in the frowning condition, $F(1.30, 10.4) = 1.37$, $p = .28$, $\eta_p^2 = 0.15$, or no-intervention condition, $F(1.86, 16.7) = 1.16$, $p = .34$, $\eta_p^2 = 0.11$.

Ratings of Perceived Exertion

As evident in Figure 6 (p. 147), RPE increased over time in each condition, and the RPE profile was similar in each condition. The main effect of time on RPE was statistically significant, $F(1.98, 17.8) = 64.1$, $p < .001$, $\eta_p^2 = 0.88$. The main effect of condition, $F(1.22, 10.9) = 0.060$, $p = .86$, $\eta_p^2 = 0.007$, and the interaction between time and condition, $F(3.31, 29.8) = 1.01$, $p = .41$, $\eta_p^2 = 0.10$, were not significant.

Feeling Scale

As evident in Figure 6, exercise-related affect became more negative (i.e., exercising became less pleasurable) over time in each condition, and the main effect of time on exercise-related affect was statistically significant, $F(1.49, 13.4) = 16.4$, $p = .001$, $\eta_p^2 = 0.65$. The main effect of condition, $F(2, 18) = 1.01$, $p = .38$, $\eta_p^2 = 0.10$, and the interaction between time and condition, $F(1.99, 17.9) = 0.42$, $p = .66$, $\eta_p^2 = 0.045$, were not significant. Figure 6 suggests that there was a trend that did not reach statistical significance. Specifically, Feeling Scale values were more negative in the thumb-press condition than the other two conditions from 60% isotime to 100% isotime.

Heart Rate

As evident in Figure 6, heart rate increased over time in each condition, and the main effect of time on heart rate was statistically significant, $F(1.44, 11.5) = 159$, $p < .001$, $\eta_p^2 = 0.95$. The main effect of condition was also significant, $F(2, 16) = 5.17$, $p = .019$, $\eta_p^2 = 0.39$. Pairwise comparisons indicated that heart rate was significantly higher in the thumb-press condition than the no-intervention condition ($p = .039$). Heart rate was not significantly different between the frowning and no-intervention conditions ($p = .40$) or the frowning and thumb-press conditions ($p = .44$). There was not a significant interaction between time and condition, $F(3.32, 26.5) = 1.02$, $p = .41$, $\eta_p^2 = 0.11$.

Cadence

As evident in Figure 6, cadence decreased over time in each condition, and the main effect of time on cadence was statistically significant, $F(1.52, 13.7) = 4.90$, $p = .032$, $\eta_p^2 = 0.35$. Although the main effect of condition, $F(2, 18) = 0.60$, $p = .56$, $\eta_p^2 = 0.062$, and the interaction between time and condition were not significant, $F(8, 72) = 1.27$, $p = .27$, $\eta_p^2 = 0.12$, Figure 6 suggests that the cadence profile was irregular in the frowning and thumb-press conditions, compared to the no-intervention condition.

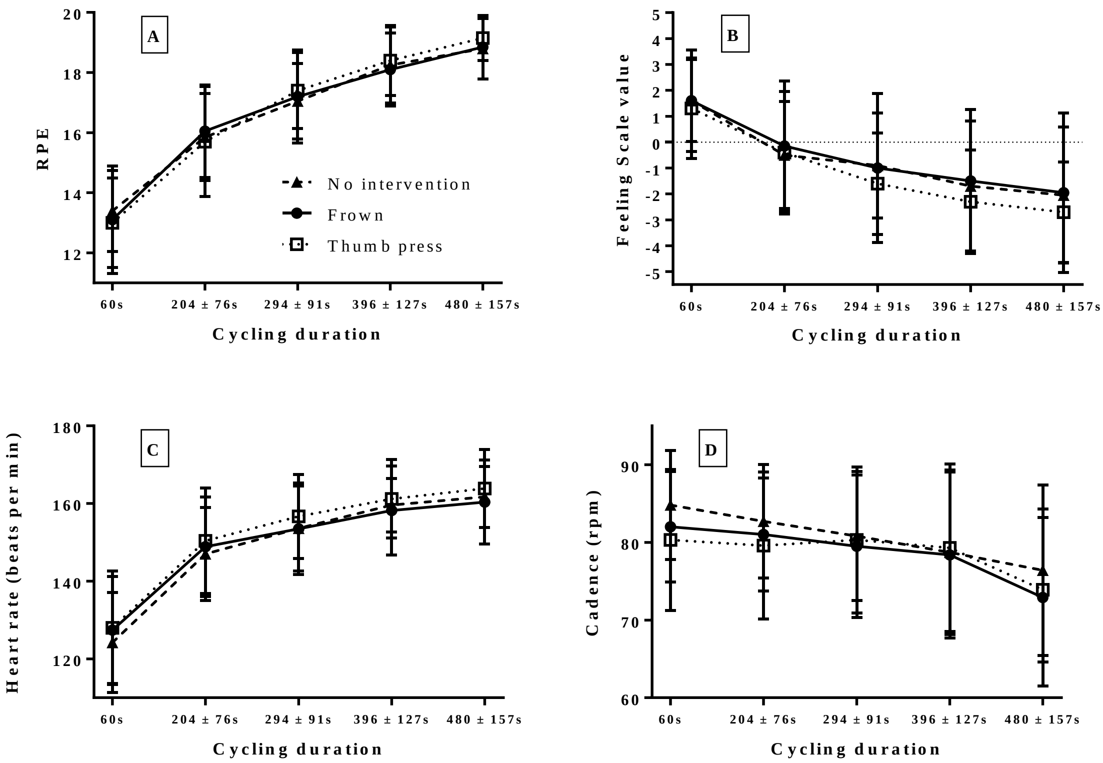

Figure 6. Mean ± standard deviation ratings of perceived exertion (RPE) (panel A), Feeling Scale (panel B), heart rate (panel C), and cadence (panel D) values over time in the frowning, thumb-press, and no-intervention conditions.

Time to Exhaustion

Time to exhaustion was similar in the frowning (609 ± 243s) and no-intervention conditions (603 ± 175s), and it was shorter in the thumb-press condition (558 ± 159s). The differences in means were not statistically significant, $F(1.24, 11.1) = 0.41$, $p = .58$,

η_p^2 = 0.043. The effects of the frowning (Δ = 0.03) and thumb-press (Δ = -0.26) interventions on time to exhaustion were trivial and small, respectively. When frowning, four of 10 participants demonstrated their worst performance, and two participants demonstrated their best performance.

Blood Lactate

Post-performance blood lactate concentrations were similar in the frowning (10.3 ± 2.44 mmol L^{-1}), thumb-press (10.6 ± 1.93 mmol L^{-1}), and no-intervention conditions (10.4 ± 2.53 mmol L^{-1}), $F(1.09, 8.68) = 0.61$, $p = .47$, $\eta_p^2 = 0.071$.

Intervention Workload

The overall workload of the frowning muscle-contraction task (out of 20, 10.2 ± 4.01) was greater than the workload of the thumb-press muscle-contraction task (7.85 ± 4.55). The difference in means was not statistically significant, $t(8) = 1.74$, $p = 0.12$, 90% CI [-0.15, 4.76]. Mean values on each subscale were generally greater for the frowning muscle-contraction task (see Table A5, Appendix U, p. 340).

Positive and Negative Affect Scale

As displayed in Table 10 (p. 149), positive and negative affect values were similar between conditions before and after the time-to-exhaustion test. Changes in positive affect in the frowning, thumb-press, and no-intervention conditions were not significantly different, $F(2, 18) = 0.94$, $p = .41$, $\eta_p^2 = 0.095$. Similarly, changes in negative affect in the frowning, thumb-press, and no-intervention conditions were not significantly different, $F(1.15, 10.4) = 0.82$, $p = .40$, $\eta_p^2 = 0.084$.

Table 10

Positive and Negative Affect Scale Values Before and After Performance

Time of scale completion	Condition	Positive affect	Negative affect
Pre-performance	Frowning	34.9 ± 7.36	11.9 ± 1.85
	Thumb press	35.8 ± 7.61	12.2 ± 2.97
	No intervention	34.3 ± 7.35	11.7 ± 2.11
Post-performance	Frowning	35.5 ± 8.77	12.5 ± 2.99
	Thumb press	34.5 ± 6.20	11.7 ± 1.77
	No intervention	35.0 ± 11.1	12.1 ± 1.45
Change (post minus pre)	Frowning	0.60 ± 7.49	0.60 ± 2.12
	Thumb press	-1.30 ± 6.00	-0.50 ± 1.90
	No intervention	0.70 ± 6.68	0.40 ± 2.12

Note. ± = mean ± standard deviation. Pre-performance and post-performance values can range from 10 to 50. Change values can range from -40 to 40. Changes in positive and negative affect were not significantly different between conditions.

Brunel Mood Scale

Changes in anger values from pre- to post-performance were negligible (out of ±16, frowning = 0.10 ± 0.32, thumb press = 0.20 ± 0.42, no intervention = 0.30 ± 0.48). The differences between conditions were not statistically significant, $\chi2(2) = 3.00$, $p = .22$. For all other BRUMS subscales, differences in change values were not significantly different ($p \geq .27$) between conditions (see Table A4, Appendix R, p. 332).

Discussion

Research on the facial feedback hypothesis suggests that afferent feedback from the bilateral CS muscles when frowning may modulate perception of effort during endurance performance. The present study applied predictions of the facial feedback hypothesis and the psychobiological model of endurance performance, and it investigated whether intentionally frowning throughout a cycling time-to-exhaustion test increased perception of effort and, consequently, reduced time to exhaustion. This study also examined the effects of frowning on affective states experienced during performance and after exhaustion. The results demonstrated that frowning did not affect perception of effort, affective states during performance or after exhaustion, or time to exhaustion. These findings suggest that frowning may not modulate perception of effort during severe-intensity (between critical power and $\dot{V}O_{2max}$) endurance performance. Novel interventions that are informed by the facial feedback hypothesis and that target the expression of a frown would therefore seem unlikely to offer an efficacious method of enhancing endurance performance.

Consistent with previous research (de Morree & Marcora, 2012), EMG activity of the CS muscles increased with cycling time, alongside perception of effort, in all conditions. Intentionally frowning during the time-to-exhaustion test, however, did not increase perception of effort (Figure 6, p. 147). These findings may suggest that although frowning expresses perception of effort, frowning does not modulate perception of effort. Alternatively, the absence of effects of frowning on perception of effort and endurance performance could be attributed to the chosen experimental procedures or confounding variables associated with the intervention. Specifically, the frowning intervention may not have affected perception of effort because participants naturally frowned in the thumb-press and no-intervention control conditions (Figure 5, p. 145). This explanation seems unlikely, however, because perception of effort was similar between conditions during the first 60% of the time-to-exhaustion tests, when CS muscle EMG RMS amplitude was low (i.e., there was little frowning) in the two control conditions. As an additional alternative explanation, intentionally frowning could have had a detrimental effect on perception of effort towards the beginning of the test before participants naturally frowned more, but this detrimental effect could have been countered by the effects of distraction; that is, the distraction caused by the frowning task could have reduced perception of effort earlier in the time-to-exhaustion test before exercise sensations dominated attention (Rejeski, 1985). This explanation seems unlikely, however, as the thumb-press task, which would also distract participants from exercise sensations, did not reduce perception of effort compared to the no-intervention control condition at the beginning of the time-to-exhaustion test.

Alternatively, as a remote voluntary contraction, intentionally frowning could have facilitated maximum effort at the end of the time-to-exhaustion test (Ebben, Leigh, & Geiser, 2008), which could have countered prior, detrimental effects of frowning on performance. This explanation seems unlikely, however, as frowning did not increase perception of effort towards the beginning of the test and final RPE values were similar across conditions. Finally, the frowning task might not have had a large enough effect on CS muscle afferent feedback to affect perception of effort. This explanation seems unlikely, however, because CS muscle EMG RMS values were much greater in the frowning condition at all time points, compared to the control conditions (Figure 5, p. 145). Therefore, based on the findings of the present study, frowning does not appear to modulate perception of effort during severe-intensity endurance performance. Conducting additional research on the effect of frowning on perception of effort using different experimental methods would allow firmer conclusions to be drawn.

Frowning did not influence affective states during or after the cycling time-to-exhaustion test. During the test, participants reported how pleasant or pleasurable they found the exercise using the Feeling Scale (Hardy & Rejeski, 1989). Before and after the time-to-exhaustion test, participants reported how they felt using the PANAS (Watson et al., 1988) and the BRUMS (Terry et al., 1999). Although frowning did not influence these measures, a substantial volume of research demonstrates that performing a facial expression can elicit feeling states that are congruent with that facial expression (e.g., Lewis, 2012) and facial expressions can amplify feeling states elicited by external stimuli (e.g., Larsen et al., 1992). In the present study, contracting the CS muscles might have elicited feeling states expressed by this facial expression, such as anger (Ekman, 2004). These effects, however, might not have endured to approximately five minutes post-intervention, which was when participants completed the PANAS and BRUMS questionnaires. Further, specific emotions experienced during endurance performance, such as anger, might not have been captured by the Feeling Scale, which is a global measure of how pleasurable the exercise feels. Nevertheless, the findings of the present study suggest that frowning does not modulate the pleasure experienced during severe-intensity endurance performance or performers' post-exhaustion affective states.

Few experimental studies have examined applications of the facial feedback hypothesis in sport and exercise contexts. As an exception, Philippen and colleagues (2012) found that exercisers reported more positive exercise-related affect and lower perception of effort when smiling compared to frowning, both at rest and during moderate-intensity cycling. As frowning did not influence perception of effort or exercise-related affect in the present study, the differences in affect and perception of effort reported by Philippen and colleagues could have been caused by the presence of a smile, rather than the absence of a frown; that is, smiling could have influenced the affective states and effort experienced. As an alternative explanation, frowning might only influence perception of effort at lower exercise intensities, and not during severe-intensity exercise. As an additional alternative explanation, the differences in findings could reflect differences in how perception of effort was defined, because Philippen et al. used a broader definition that captured additional exercise sensations to effort (discomfort). The present study may also have been more successful at disguising the research hypotheses from participants. Future research that includes a control condition could further explore the effects of frowning and smiling on exercise-related affect and perception of effort during moderate-intensity exercise.

Although the frowning intervention did not affect the dependent variables, the thumb-press intervention increased heart rate compared to the no-intervention control condition. This may be because contracting the thumb muscles increased the oxygen cost of the severe-intensity cycling (Özyener, Whipp, & Ward, 2012). The thumb-press intervention was also associated with a greater decline in exercise-related affect from

60% isotime and greater decreases in both positive and negative affect from pre- to post-performance; these trends, however, did not reach statistical significance with the chosen sample size. These trends are unlikely to have been caused by the workload of the thumb-press task, because the statistical analyses indicated that the overall perceived workload was either similar between muscle-contraction tasks or greater for the frowning task (the individual workload items also followed this trend). As the thumb-press intervention was included to control for the physical and mental demands of performing a muscle-contraction task while exercising and does not simulate a behaviour performed by cyclists, these findings do not have implications for the facial feedback hypothesis or sport science application.

Limitations

The thumb-press task was included to control for the mental (e.g., dual-task demands, distraction) and physical demands of maintaining a muscle contraction *per se*. The perceived workloads of the frowning and thumb-press tasks were similar. As evident in Figure 5 (p. 145), however, changes in EMG RMS over time were different for the two muscle-contraction tasks; CS muscle EMG RMS increased over time in the frowning condition, whereas thenar muscle EMG RMS decreased over time in the thumb-press condition. The decrease in thenar muscle EMG RMS could have been caused by participants pressing less firmly over time, due to fatigue in the thenar muscles. The dissimilar changes in EMG RMS over time suggest that the physical demands of the two muscle-contraction tasks were different, which perhaps accounts for the increase in heart rate observed only in the thumb-press condition. Although the difference between muscle-contraction task demands could have caused confounding effects, these effects would not have changed the conclusions drawn, because the frowning task did not affect the main dependent variables compared to the no-intervention control condition. Future research that replicates the frowning task, however, should consider an alternative control task. As an additional limitation, the sample size was chosen to detect a moderate effect of frowning on time to exhaustion. If the true effect of frowning on time-to-exhaustion is small, then the study is underpowered. There do not appear to be trends in the data, however, that are consistent with the study hypotheses and that do not reach statistical significance.

Future Research

Although frowning did not influence perception of effort in the present study, it may be premature to conclude that frowning does not modulate perception of effort. Additional research using different methods could allow firmer conclusions to be drawn. Although intentionally frowning did not increase perception of effort in the present study, the severe-intensity cycling naturally caused some frowning in the two control conditions (Figure 5, p. 145). The effects of intentionally frowning might therefore have been masked by the spontaneous frowning that was evident in the control conditions. Future research might therefore examine the effects of inhibiting a frown during a time-to-exhaustion test on perception of effort and endurance performance. Specifically, research could compare pre- to post-treatment changes in perception of effort and cycling time to exhaustion between populations choosing to receive Botox injections for the treatment of frown lines and populations choosing alternative cosmetic injections that do not affect facial muscles (Davis, Senghas, Brandt, & Ochsner, 2010; Havas, Glenberg, Gutowski, Lucarelli, & Davidson, 2010). Botox paralyses muscles in the injected area by blocking the release of the neurotransmitter acetylcholine (Hambleton, 1992), and it would therefore inhibit afferent feedback from the CS muscles. Botox studies have already demonstrated the role of the CS muscles in expressing emotion (Heckmann et al., 2003), processing emotional language (Havas et al., 2010), and regulating mood states (Wollmer et al., 2012). If afferent feedback from the CS muscles when frowning modulates perception of effort, then interventions preventing the expression of a frown could be used to enhance endurance performance. That is, research examining the effects of interventions that inhibit frowning would have greater relevance to application than interventions that increase frowning. In addition, future research could examine the effect of frowning on perception of effort at a lower exercise intensity that naturally causes less frowning. Moreover, future research could use different interventions to encourage frowning. For example, researchers could use electrical muscle stimulation (EMS) to elicit CS muscle contraction during exercise. Unlike the intervention used in the present study, EMS would cause frowning without requiring conscious effort from participants, and it would remove confounding effects that could have influenced the findings of the present study, such as dual-task demands and distraction.

Future research could also examine whether interventions that encourage smiling, such as words or images on display at mass-participation exercise events or on cycling trails, can cause exercise to feel more pleasurable. The modulation version of the facial feedback hypothesis proposes that facial expressions amplify congruent emotional experiences elicited by external stimuli (Davis et al., 2009), such as the pleasure experienced during exercise. As exercise feels more pleasurable at intensities below the lactate and ventilatory thresholds (Ekkekakis et al., 2011), smiling interventions might be particularly efficacious at moderate exercise intensities. If smiling interventions are efficacious at increasing the pleasure experienced during moderate-intensity exercise, then they could potentially be used to promote physical activity, because the experience of pleasure during moderate-intensity exercise is associated with greater levels of moderate and vigorous physical activity (Schneider, Dunn, & Cooper, 2009). Additional research on the effects of smiling on exercise-related affect could therefore have substantial impact.

Conclusions

Although frowning contributes to the expression of perceived effort during endurance performance, the results of this study suggest that frowning is unlikely to modulate perception of effort because intentionally frowning throughout a cycling time-to-exhaustion test did not affect perception of effort or cycling time to exhaustion. Interventions that are informed by the facial feedback hypothesis and that target the expression of a frown would therefore seem unlikely to offer an efficacious method of enhancing endurance performance. Additional research on the effects of frowning on perception of effort and endurance performance that uses different experimental methods would allow firmer conclusions to be drawn.

Notes

[1] See Table 2 (p. 12) for the exercise intensity domains. During severe-intensity exercise, exercisers perform at a power output between critical power and $\dot{V}O_{2max}$, and they will typically be able to perform for up to 30-45 minutes before exhaustion. Heavy-intensity exercise, in contrast, can be performed for up to 3-4 hours (Burnley & Jones, 2007).

[2] CS muscle EMG data is missing from one frowning trial because of equipment malfunction. Two heart rate values are missing because of equipment malfunction. Thenar muscle EMG data and associated workload data were excluded for one thumb-press trial because the electrodes became loose during the trial. One post-performance lactate value was excluded because of difficulty collecting a full sample.

Chapter 5

The Effect of Motivational Self-Talk on Performance in an Ultramarathon

Alister McCormick, Carla Meijen, and Samuele Marcora

Endurance Research Group, School of Sport & Exercise Sciences, University of Kent, Medway Building, Chatham Maritime, Kent, ME4 4AG, United Kingdom

Note to the interested reader: Additional data is being collected for this study in 2016 and will be available on request.

Aim of Chapter 5

The main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance. Chapter 5 used a randomised, controlled experiment to examine the effect of a motivational self-talk intervention on performance in an ultramarathon. It addressed the third and final research aim of the thesis, which was to examine the effect of a psychological skills training intervention on performance in a real-life endurance event. Earlier chapters informed Chapter 5. As reported in Chapter 2 (systematic review), few studies have examined the effect of a psychological intervention on performance in a real-life endurance event, particularly using a randomised, controlled experiment. In addition, few studies have compared the effect of a psychological intervention against a placebo or alternative control treatment. In Chapter 5, participants in the control group received an alternative control treatment. These participants received a concentration grid intervention that was designed to be similar in duration, perceived value, and procedure to the self-talk intervention, but it was not expected to influence ultramarathon performance. Furthermore, no published studies on the psychological determinants of endurance performance have reported whether participants continued to use interventions after their commitment to the study, which could shed light on long-term intervention adherence and perceived intervention value. In Chapter 5, a six-month follow-up was included to determine whether ultramarathon runners continued to use self-talk in training and endurance events. Moreover, data reported in earlier chapters informed the nature of the intervention. Self-talk was chosen because research at lower risk of bias demonstrated that it is efficacious in controlled conditions (Chapter 2). The psychological demands of endurance events were also considered (Chapter 3). Specifically, participants were taught to use motivational self-talk to counter thoughts about withdrawing effort and to cope with stressors such as getting lost or falling behind targets.

Abstract

No published studies have examined the effect of psychological skills training on performance in a real-life endurance event using a randomised, controlled experiment. The present study examined the effect of motivational self-talk on performance in a 60-mile, overnight ultramarathon. In addition, this study examined the effects of self-talk on pre-event self-efficacy and perceived control, which influence challenge responses to upcoming competition, and it examined whether participants continued to use self-talk after their commitment to the study. Data were collected before, during, and after an annual ultramarathon on two consecutive years. After a standardised intake interview that was conducted by video call or telephone, 21 ultramarathon runners (19 British, 18 male, age = 38.6 ± 8.9 years) were matched by their estimated $\dot{V}O_{2max}$ and randomly allocated to a motivational self-talk group or an alternative control group. Ultramarathon runners in the self-talk group used a workbook to identify motivational self-talk statements to use during the beginning, middle, and later stages of the ultramarathon, to counter thoughts about withdrawing effort, and in response to stressors (e.g., getting lost). Ultramarathon runners in the control group used concentration grids to develop their concentration. Results demonstrated that learning to use motivational self-talk did not affect pre-event self-efficacy or perceived control. Ultramarathon runners in the self-talk group finished on average 25 minutes faster than runners in the control group. Practically, the true effect size at the population level is unlikely (16.5% probability) to be harmful, possibly trivial (27.1% probability), and possibly beneficial (56.3% probability). Most participants reported still using self-talk six months after the ultramarathon, particularly in endurance events and to a lesser extent in training. Although motivational self-talk possibly produced a performance enhancement that might benefit ultramarathon runners, additional data are required to draw firm conclusions.

Introduction

Psychological skills training (PST) can enhance endurance performance. Self-talk, imagery, goal setting, and PST packages including multiple PST strategies consistently enhance endurance performance in non-competitive laboratory and field-based endurance tasks (Chapter 2). Few studies, however, have examined the effects of psychological interventions such as PST on performance in actual endurance-distance competitions, and these studies (Lindsay et al., 2005; Sheard & Golby, 2006) showed equivocal intervention effects. People typically perform better in endurance tasks when competing against others (e.g., Corbett et al., 2012). Further, athletes need to manage additional stressors, and associated emotional responses, before (Mellalieu et al., 2009) and during (Chapter 3) competition, compared to those typically present in experimental conditions. It is therefore important to demonstrate that the performance benefits of PST generalise to real-life competition. To date, few studies of endurance and other sport performances have measured the effects of a psychological intervention on the competitive performances of athletes using a randomised, controlled experiment (Andersen, 2009; G. L. Martin et al., 2005). Randomised, controlled experiments are the most rigorous experiments for demonstrating a cause-and-effect relationship between an intervention and an outcome (e.g., Shadish, Cook, & Campbell, 2002). The present study is the first randomised, controlled experiment to examine the effects of PST on performance in an endurance-distance competition. Specifically, this study examined the effect of motivational self-talk on performance in an ultramarathon.

Ultramarathons are increasing in popularity (Cejka et al., 2014; Gerosa, Rüst, Rosemann, & Knechtle, 2014; Hoffman, Ong, & Wang, 2010). For example, from 1998 to 2011, approximately 112,000 athletes (86% male) finished a 100-km ultramarathon worldwide, and the number of finishers increased each year (Cejka et al., 2014). Ultramarathons are particularly popular with middle-aged participants, especially males

(Cejka et al., 2014; Knechtle, Rüst, Rosemann, & Lepers, 2012). Psychological research suggests that five broad experiences characterise involvement in ultramarathon running: 1) the support, common personal bonds, and camaraderie of being part of an ultramarathon community; 2) physical (e.g., training, nutrition, hydration), tactical (e.g., preparing equipment and clothing), and mental aspects (e.g., reflecting on previous experiences) of preparing for an ultramarathon; 3) using mental skills to manage performance during a race; 4) having opportunities to push perceived capabilities, to experience nature, and to have spiritual experiences; and 5) the feelings of accomplishment and euphoria experienced after completing an ultramarathon (Simpson et al., 2014). Although research has shed light on the experiences of ultramarathon runners and the coping strategies ultramarathon runners use (Acevedo, Dzewaltowski, Gill, & Noble, 1992; Holt et al., 2014; Simpson et al., 2014), no published studies have examined the effects of PST on performance in an ultramarathon. Further, no studies have examined the effects of PST on performance in long-distance running events of at least half-marathon distance (Chapter 2). The ultramarathon studied in the present study was 60 miles (96.6 km).

Self-talk can be used for motivational or instructional purposes (e.g., Gammage, Hardy, & Hall, 2001). Motivational self-talk is typically used for psyching up, maximising effort, building confidence, and creating positive mood states, whereas instructional self-talk is typically used for directing attention, executing technique, supporting kinaesthetic attributes of a skill, and implementing strategy (Hatzigeorgiadis et al., 2011). Self-talk facilitates performance across a range of sport and exercise tasks (Hatzigeorgiadis et al., 2011; Tod, Hardy, & Oliver, 2011), and practising self-talk leads to greater effects on performance (Hatzigeorgiadis et al., 2011). In the present study, motivational self-talk was chosen over instructional self-talk and other PST interventions for four main reasons. First, as self-talk is simple to learn and apply

(Hatzigeorgiadis et al., 2011), it could be a time-efficient intervention for a population that often has little free time (Simpson et al., 2014). Second, motivational self-talk produces greater effects than instructional self-talk during gross motor skill tasks such as running (Hatzigeorgiadis et al., 2011). Third, motivational self-talk has been shown to reduce perception of effort and enhance endurance performance in randomised, controlled experiments (Barwood et al., 2015; Blanchfield, Hardy, de Morree, et al., 2014). Finally, motivational self-talk is a versatile strategy that could serve multiple functions during an ultramarathon.

Motivational self-talk could enhance ultramarathon performance through different mechanisms. According to the psychobiological model of endurance performance, endurance athletes make pacing decisions to control the increase in their perception of effort so that they avoid exhaustion and experience maximum effort at the end of the event (Marcora & Bosio, 2007; Marcora, 2010a). Motivational self-talk reduces perception of effort, which means that athletes can use motivational self-talk to increase their pace whilst experiencing the same effort (Barwood et al., 2015). In addition to reducing perception of effort, motivational self-talk could benefit ultramarathon performance by helping ultramarathon runners to cope with stressors experienced during the ultramarathon. Ultramarathon runners must overcome muscle cramping and injuries, gastrointestinal problems, thoughts about quitting, and experiences of exertion, and they need to carefully pace themselves to ensure that they meet cut-off times whilst avoiding premature exhaustion (Holt et al., 2014; Simpson et al., 2014). As the ultramarathon in the present study was completed overnight, additional event-specific stressors include navigation in the dark and sleep deprivation, which can impair cognitive performance (e.g., navigation), disturb mood, and increase perception of effort (Hurdiel et al., 2014; Oliver, Costa, Walsh, Laing, & Bilzon, 2009; J. P. R. Scott, McNaughton, & Polman, 2006). Using motivational self-talk as a coping strategy when experiencing stressors could prevent the stressors from eliciting negatively-toned emotions (Lazarus, 2000) and, consequently, from undermining their motivation to sustain effort and their ability to concentrate on important cues such as navigation cues (Dugdale et al., 2002; Martinent & Ferrand, 2009). Indeed, ultramarathon runners have emphasised the importance of maintaining positive inner dialogue throughout an ultramarathon, particularly during difficult moments (Simpson et al., 2014). As an additional mechanism, research demonstrates that intentionally using self-talk statements during a "psychological crisis", which is characterised by a strong impulse to quit and thoughts about the costs of continuing and the benefits of quitting, can prevent the crisis from having a detrimental effect on long-distance running performance (Schüler & Langens, 2007, Study 2).

In addition to examining the effect of motivational self-talk on ultramarathon performance, this study examined whether learning self-talk increased pre-event self-efficacy and perceived control. When the outcome of a competition is important to an athlete, the athlete may perceive the competition as a challenge or a threat, depending on whether they appraise their coping resources as sufficient for the demands of the competition (M. Jones et al., 2009). Challenge states are suggested to be beneficial, because they reduce mentally-draining self-regulation of psychological states, encourage positively-toned emotions, improve decision making (e.g., pacing decisions), facilitate attention to task-relevant cues, support sustained effort, and optimise performance (M. Jones et al., 2009). Self-efficacy, perceptions of control, and achievement goals influence whether athletes experience challenge or threat states in response to competition. Specifically, an athlete is more likely to experience a challenge state if they possess high self-efficacy, possess perceptions of control, and strive towards achieving goals (M. Jones et al., 2009). In the present study, learning motivational self-talk before the ultramarathon could increase the runners' belief that they have the psychological skills necessary to cope with the event demands and achieve their goal (i.e., self-efficacy), and ensure that they perceive themselves as having sufficient control over their ability to display those skills (i.e., perceived control). The present study therefore examined whether learning motivational self-talk can promote challenge states in response to upcoming competitions.

The main aim of the present study was to examine the effect of motivational self-talk on performance in an ultramarathon. This study also examined whether learning self-talk influenced pre-event self-efficacy and perceived control, which influence challenge responses to upcoming competition. It was hypothesised that participants who learned to use self-talk would have higher pre-event self-efficacy and perceived control and finish in a faster time, compared to a control group. Further, this study aimed to determine whether participants were still using self-talk six months after receiving the intervention, which could indicate whether they found learning self-talk valuable. Studies examining the effects of PST on endurance performance have not reported whether participants continued to use the taught intervention after they finished their commitment to the study (Chapter 2).

Methods

Design

A randomised, controlled, posttest-only experimental design was chosen for the endurance-performance dependent variable. For some psychological variables, however, pre- and post-intervention comparisons were possible. Participants were randomly assigned to either an experimental group (motivational self-talk) or an alternative control treatment group (concentration grid). Alternative control treatments are similar in duration, perceived value, and procedure to the experimental treatment, but they target different outcomes (W. Borg, 1984). These control groups reduce the likelihood of sources of bias (e.g., withdrawal and dropout, contamination) that are present when the control group does not receive an intervention. The experimental group and the alternative control group were matched for expected aerobic fitness. Specifically, participants were ranked by their estimated $\dot{V}O_{2max}$, and a coin toss was used to determine treatment allocation (Hopkins, 2000).[1]

The Event

The ultramarathon is an annual 60-mile race along the Thames Path in South England. The ultramarathon begins at 8pm, and there is a 15-hour cut off. The route follows the River Thames from Radley, Oxford, to the source of The Thames in Kemble, the Cotswolds. Participants navigate a flat, rural terrain that passes through villages. The ultramarathon is self-supported. Participants carry food, water, and clothing, and they navigate using head torches and supplied route maps. Water and medical attention are available at three checkpoints that are spaced 15 miles apart. There are cut-off times for each checkpoint. Some participants treat the ultramarathon as preparation for a 184-mile ultramarathon (80-hour cut off) along the same route, and they therefore carry additional equipment with them (e.g., sleeping and cooking equipment). Data were collected before, during, and after two annual 60-mile ultramarathons (May 2014 and May 2015). Performance times of all entrants (including people who did not participate in the research) in the first and second years were 835 ± 88 minutes and 841 ± 103 minutes, respectively. A two-tailed, independent samples *t*-test indicated that the difference in performance times was not statistically significant, $t(52) = 0.25$, $p = .81$.

Participants

All runners who were registered for the ultramarathon were invited to participate. Potential participants were told that the study was investigating whether a consultation with a sport psychologist influences endurance runners' experiences before and during a long-distance event. As summarised in Figure 7 (p. 167), 23 people who registered for the ultramarathon volunteered to participate in the study. After two dropouts (both male), 21 participants attended the event and were included in the analyses. Eighteen of the 21 participants were male, and three were female. Nineteen were British, one was American, and one was Canadian (age = 38.6 ± 8.9 years, height = 178 ± 10 cm, weight = 73.5 ± 8.0 kg, weekly training hours = 8.9 ± 3.9, events of at least half-marathon distance during the previous 12 months = 5.5 ± 3.7, male estimated $\dot{V}O_{2max}$ = 50.3 ± 9.0 $ml \cdot kg^{-1} \cdot min^{-1}$, female estimated $\dot{V}O_{2max}$ = 42.0 ± 4.4 $ml \cdot kg^{-1} \cdot min^{-1}$). Participants had little prior experience with PST, particularly using self-talk systematically. During an intake interview, no participants reported past experience working with a sport psychologist. Further, when describing the mental strategies they use during endurance events, only two participants referred to self-talk statements. These two participants (both were randomly assigned to the control condition) referred to saying motivational things to themselves. The most common psychological strategy (referred to by 11 participants) was race chunking, which involves breaking the distance down into a series of shorter, more manageable distances.

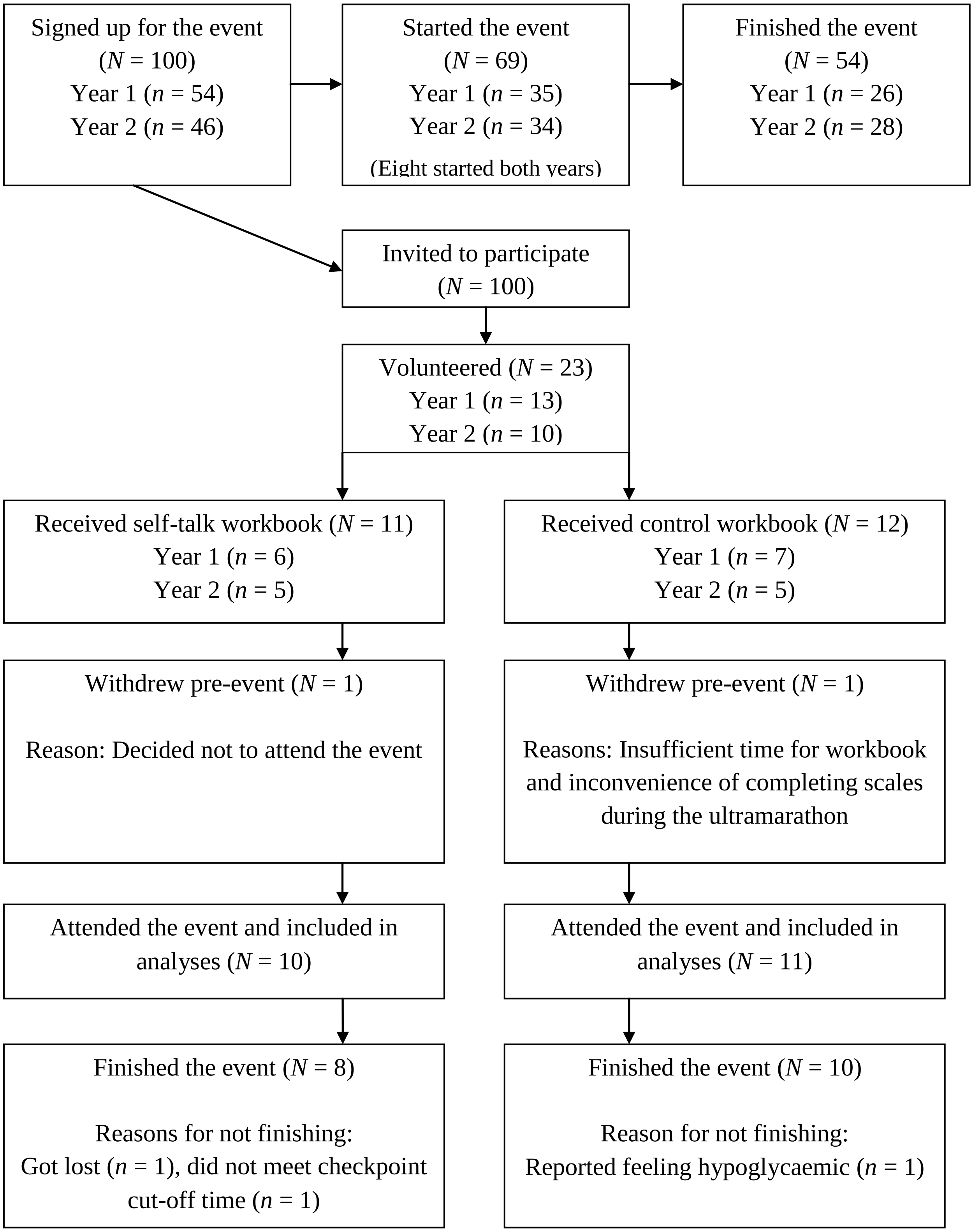

Figure 7. Flowchart of event participation, study participation, and study dropouts.

Procedure

Ethical approval was granted by the department ethics committee. Figure 8 (p. 169) provides an overview of the timeline, including data-collection and intervention-delivery dates. Self-report data were mainly collected using four online surveys that were created using Bristol Online Survey (www.onlinesurveys.ac.uk) and distributed by email. One battery of questionnaires was completed on paper 30-90 minutes before the event (Appendix V, p. 341). Participants provided informed consent when they completed the first survey, and they signed a consent form in person at the event (Appendix W, p. 345). The interventions were distributed by email, following an intake interview conducted by video call or telephone. With consideration to missing self-report data, all participants completed Survey 1, 18 participants (86%) completed Survey 2 (two participants in the self-talk group and one in the control group did not complete it), 19 participants (90%) completed the pre-event questionnaires (two participants in the self-talk group arrived late), all participants completed Survey 3, and 20 participants (95%) completed Survey 4 (one participant in the self-talk group did not complete it). Self-report data were complete for 17 participants (81%).

Variables

Data were collected before, during, and after the ultramarathon. The variables are described in the order that they were measured (see Figure 8).

Estimated $\dot{V}O_{2max}$. $\dot{V}O_{2max}$ was estimated using data collected in Survey 1 and corresponding formulas for males (Malek, Housh, Berger, Coburn, & Beck, 2005) and females (Malek, Housh, Berger, Coburn, & Beck, 2004). Reported age (years), weight (kg), height (cm), hours per week of exercise, duration that participants have consistently (no more than one month without exercise) been exercising (years), and a typical session rating of perceived exertion (6-20 scale) determine the estimated $\dot{V}O_{2max}$ values.

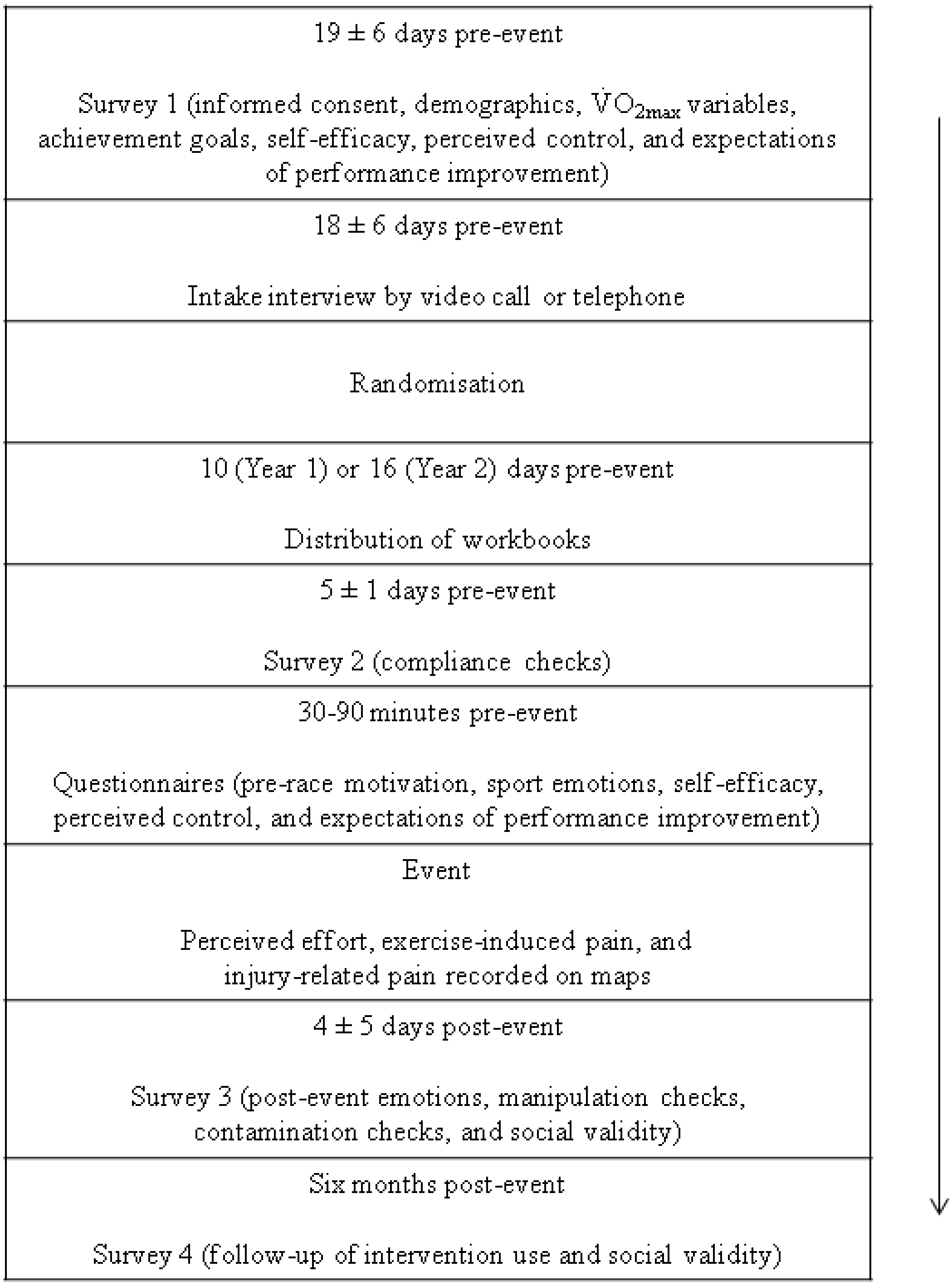

Figure 8. Overview of the study timeline.

Achievement goals. Achievement goals were measured in Survey 1 using the Achievement Goal Questionnaire for Sport (AGQ-S) (Conroy, Elliot, & Hofer, 2003). Specifically, participants indicated the extent to which 12 statements were true of them just before an important endurance event, using a seven-point scale (1 = "Not at all like me”, 7 = “Completely like me”). Three statements corresponded with mastery-approach (e.g., “I am striving to perform as well as I possibly can”), mastery-avoidance (e.g., “My aim is to avoid not performing as well as I possibly can”), performance-approach (e.g., “I am striving to do well compared to others”), and performance-avoidance goals (e.g., “My aim is to avoid performing worse than others”). Wording adjustments were made based on the recommendations of Elliot and Murayama (2008). For example, all items opened with “My aim is to”, “My goal is to”, or “I am striving to”. The revised AGQ-S is presented in Appendix X (p. 349).

Self-efficacy and perceived control. A self-efficacy scale was designed following the guidance of Bandura (2006). Participants rated how certain they were (0-100 degree of confidence) that they could do each of 10 things during the ultramarathon. “Cannot do at all”, “moderately certain can do”, and “highly certain can do” anchors were placed next to 0, 50, and 100 on the scale, respectively. The 10 demands reflected demands of endurance events in general (e.g., “Cope with things going wrong”, “Pace yourself effectively”) and anticipated demands of this specific event (e.g., “Deal with boredom”, “Cope with the lack of sleep”). The former demands were informed by the qualitative data analysed in Chapter 3. Participants also rated how much control they perceived their self to have over each of the 10 demands by selecting a number from one (“no control”) to 10 (“complete control”). Overall self-efficacy and perceived control values were mean values of the 10 ratings. The self-efficacy and perceived control questionnaire is presented in Appendix V (p. 341), and it was completed in Survey 1 and at the event before the start.

Performance expectations. Expectations of performance improvement were measured to determine the possibility of a placebo effect (Boot et al., 2013). Pre-randomisation (Survey 1), participants rated their degree of agreement with the following statement on a seven-point Likert scale (1 = “Very strongly disagree”, 7 =

"Very strongly agree"): "Psychological interventions like the one I will receive have the potential to improve performance in endurance events like the (ultramarathon name)". Before the event start, participants rated their degree of agreement with the following statement on the same scale: "The psychological intervention I received has the potential to improve performance in endurance events like the (ultramarathon name)".

Pre-event motivation. Before the event start, participants rated their agreement with two statements ("I am motivated to participate in the [ultramarathon name]" and "I am motivated to race against others in the [ultramarathon name]") on a five-point Likert scale (0 = "Not at all", 4 = "Extremely").

Sport emotions. Participants completed the Sport Emotion Questionnaire (M. V Jones, Lane, Bray, Uphill, & Catlin, 2005) on two occasions. This questionnaire, which is specific to sport, contains 22 items, and it assesses anger, anxiety, dejection, excitement, and happiness. Before the event start, participants rated how they felt at that moment in relation to the upcoming competition (see Appendix V, p. 341), and they were informed that they would use an online survey to retrospectively rate how they felt after they finished the event. The four fatigue items of the Brunel Mood Scale (Terry et al., 1999) were included among the 22 items. Both measures use the same five-point scale, which ranges from 0 ("not at all") to 4 ("extremely"). As part of Survey 4, participants retrospectively rated how they felt after they finished the ultramarathon.

Perception of effort and pain. Participants received maps to navigate the route. Nine *research points* were marked on the maps, near to identifiable landmarks. At each research point, participants were required to rate their perception of effort, exercise-induced pain, and injury-related pain by marking a value onto a scale that was printed, with verbal anchors, on the map (year 1) or carried with their map (year 2).[2] Participants rated their overall perception of effort using the 15-point ratings of perceived exertion (RPE) scale (G. A. Borg, 1998), and they rated the intensity of exercise-induced pain and injury-related pain using 0-10 pain scales (Cook, O'Connor, Eubanks, Smith, & Lee, 1997).

In advance of the intake interview, participants were emailed an information booklet (Appendix Y, p. 351) that detailed how to use each of the scales. This information booklet included the following: a preview of the maps; definitions of perception of effort, exercise-induced pain, and injury-related pain; clarification of the differences between these variables; and instructions in how to use the rating scales. Perception of effort was defined as how effortful, heavy, and strenuous the exercise feels (Marcora, 2010a). Exercised-induced pain was defined as the pain that is produced by muscle burn and ache as a result of repeated or prolonged muscular contraction, whereas injury-related pain was defined as the pain that may result from injury (e.g. blisters, twisted ankle). The content of this information booklet was summarised during the intake interview. Participants were asked to practise using the scales during at least one training run. The experimenter checked that participants understood how to use the RPE and pain scales in person, before the start of the event.

Performance. Event officials recorded each participant's finishing time to the nearest minute. Performance times were downloaded from the official website of the ultramarathon.

Manipulation checks. Following the event (Survey 3), manipulation-check questions were used to determine whether participants in the self-talk group used the workbook to identify self-talk statements (Yes/No), to what extent these participants used self-talk statements during the ultramarathon (five-point Likert scale), whether self-talk statements were helpful (Yes/No), and the occasions and purposes of using self-talk statements (qualitative data). Participants in the concentration-grid group used the same five-point Likert scale (1 = "never", 5 = "a great deal") to report the extent to which they used self-talk statements during the event.

Contamination checks. Following the event, contamination questions were used to determine whether participants were aware of the other intervention and, if so, whether they had subsequently researched this intervention.

Social validity. Social validation is used to determine satisfaction with an intervention (Page & Thelwell, 2013). Following the event, participants used a five-point Likert scale to rate the extent to which an improvement in long-distance running performance is important to them, the extent to which an improvement in concentration is important to them (control group only), the extent to which the intervention-delivery methods were acceptable, the extent to which they viewed changes in their long-distance running performance to be significant, and the extent to which they viewed changes in their concentration to be significant (control group only) (1 = "strongly disagree", 5 = "strongly agree") (Wolf, 1978). Six months after the event (Survey 4), participants re-rated the extent to which they viewed changes in their long-distance running performance and concentration to be significant.

Follow-up of intervention use. Six months after the event, participants reported whether they were still using self-talk statements (self-talk group) or concentration grids (control group) using a five-point Likert scale (1 = "Not at all", 5 = "A great deal"). Participants in the self-talk group were asked whether they used self-talk statements in training during the previous month and during their most recent long-distance running event. They also provided information on the occasions and purposes of using self-talk statements. After the six-month follow-up, participants received the second workbook and information on how to use the concentration grid to practise using self-talk statements (Appendix Z, p. 357).

Interventions

Following an intake interview via video call or telephone, the interventions were delivered remotely using workbooks that included educational content and exercises.

Practitioner. The primary researcher was close to completing three years of supervised practice as a sport and exercise psychologist during the first year of data collection, and he was a registered sport and exercise psychologist during the second year. This researcher co-designed the workbooks and intake protocol, and he conducted all intake interviews. The second author, a registered sport and exercise psychologist, contributed towards the design of the workbook and intake protocol.

Intake interview. Participants lived outside of the researchers' geographical area. The primary researcher ran the intake interviews by video call (n = 14) when it was feasible for the participant, and he spoke to the rest of the participants by telephone (n = 7). The researcher followed a set protocol during each intake interview (Appendix AA, p. 359). The researcher and participant discussed the following topics during each intake: the participant's involvement in distance running and the specific ultramarathon; the participant's expectations and goals for the ultramarathon; what sport psychology is and the participant's experiences with it; psychological strategies already used by participants; and the format of the workbook. The researcher emailed participants information on the RPE and pain scales in advance of this intake, and the researcher summarised how to use these scales during the intake. The researcher also asked whether participants knew any other competitors in the ultramarathon, and participants were asked not to discuss the content of their workbook with other competitors, including competitors in the following year's ultramarathon. The intakes lasted 32 ± 7 minutes.

Workbooks. To the extent possible, the workbooks were presented in a similar format. Both workbooks included educational material, exercises for participants to complete, and four logs that would each take up to five minutes to complete. The workbooks were distributed one day after the final intake interview.

Self-talk workbook (Appendix AB, p. 362). The self-talk workbook was adapted from the workbook used by Blanchfield, Hardy, de Morree, and colleagues (2014). Following a brief introduction to self-talk statements, participants were asked to listen to their thoughts during a training run, and they rated the effects that self-talk statements had on how they felt. Participants then compared their statements to 32 motivational statements that were located in the self-talk literature (Blanchfield, Hardy, de Morree, et al., 2014; A. Miller & Donohue, 2003) or PST consultancy notes, and they picked four statements from the two lists that would be valuable during the beginning, middle, or later stages of the ultramarathon. Participants were also encouraged to use motivational statements to counter thoughts about withdrawing effort and in response to "critical moments" such as hitting the wall, getting lost, and falling behind targets. Participants were encouraged to practise using statements in training until the ultramarathon, because practising self-talk leads to greater effects on performance (Hatzigeorgiadis et al., 2011). Participants were asked to complete four logs detailing their use of self-talk statements.

Concentration workbook (Appendix AC, p. 373). The importance of concentration in sport was briefly introduced. The workbook then introduced the concentration grid (Harris & Harris, 1984) and explained how participants could use it to develop their concentration. Participants were encouraged to complete at least two concentration grids each day, on as many days as possible, until the ultramarathon, and they were asked to practise in both quiet and distracting environments. Participants were given 20 concentration grids, and they were asked to complete four logs detailing their use of the concentration grid. As this workbook aimed to develop concentration rather than enhance performance, care was taken not to suggest performance-relevant cues that participants could pay attention to during the ultramarathon or to introduce additional psychological strategies that participants could use.

Compliance checks. Participants completed a survey 5 ± 1 days before the ultramarathon (Survey 2) that was used to determine whether participants had read the workbook, the number of days they had practised their psychological strategy, and the number of logs they had completed. In as many words as they wished, participants also provided their first impressions of the workbook and the psychological strategy, and they were given the opportunity to ask questions. Answers to questions were sent to all participants who were using the same workbook. Participants were also asked to submit their workbook logs to the researcher when they attended the ultramarathon or by email.

Data Analysis

The assumptions of all statistical tests were checked, and the chosen statistical tests were judged to be appropriate for the analysed data. A one-tailed, independent-samples *t*-test was used to determine if there was a statistically-significant difference in the performance times between groups. A Glass's delta (Δ) effect size value was also calculated (Hojat & Xu, 2004). Small, moderate, and large effect size anchors are 0.20, 0.50, and 0.80, respectively (Cohen, 1988). To address the practical significance of the effect on performance—particularly considering the small sample size—the probabilities that the true effect size is beneficial (> 0.20), trivial (between ± 0.20), or harmful (< -0.20) were calculated using a magnitude-based inferences spreadsheet (http://sportsci.org/resource/stats/generalize.html) (Batterham & Hopkins, 2006). Mixed ANOVAs (condition by time) were used to determine whether the intervention influenced changes in self-efficacy and perceived control. Partial eta squared (η_p^2) effect sizes are presented for these ANOVAs. Small, moderate, and large effect size anchors are 0.01, 0.06, and 0.14, respectively (Cohen, 1988). Mann-Whitney U tests were used to compare pre-post changes in expectations of performance improvement and pre-event motivation values between groups. A Wilcoxon signed-rank test was used to compare within-subject pre-event motivation to participate and to race against others. Two-tailed independent *t*-tests or Mann-Whitney U tests (depending on whether participant scores were normally distributed) were used to compare changes in emotions and fatigue from pre-event to post-event for ultramarathon finishers. Friedman tests of differences among repeated measures were used to determine if there were differences in scores on the AGQ-S subscales. Mean and standard deviation values are reported as measures of central tendency and variation for continuous data, and median and interquartile range (IQR) values are reported for ordinal data. Qualitative data collected through workbook logs, the post-event survey (Survey 3), and the six-month follow-up survey (Survey 4) were organised into themes to determine the functions of using self-talk.

Results

Achievement Goals

Mean scores on the mastery-approach goals (17.2 ± 2.40) subscale were greater than scores on the mastery-avoidance (11.0 ± 4.95), outcome-approach (10.9 ± 3.95), and outcome-avoidance subscales (10.1 ± 5.01) (scores on each subscale can range from 3 to 21.). The differences were statistically significant, $\chi^2(3) = 23.3$, $p = < .001$. Pairwise comparisons indicated that the mastery-approach subscale scores were greater than each other subscale (all $p < .01$). Differences between scores on the mastery-avoidance, outcome-approach, and outcome-avoidance subscales were not statistically significant (for all pairwise comparisons, $p = 1.00$).

Self-Efficacy

For participants in the self-talk group, self-efficacy decreased from 89.6 ± 6.19 when Survey 1 was completed (pre-randomisation) to 85.2 ± 7.10 (out of 100) at the event before the start. For participants in the control group, self-efficacy decreased from 86.8 ± 8.57 to 86.4 ± 9.76. The main effect of time, $F(1, 17) = 1.13$, $p = .30$, $\eta_p^2 = 0.063$, the main effect of condition, $F(1, 17) = 0.069$, $p = .80$, $\eta_p^2 = 0.004$, and the interaction between time and condition, $F(1, 17) = 0.82$, $p = .38$, $\eta_p^2 = 0.046$, were not statistically significant. Spearman's rank-order correlations showed that negative correlations between pre-randomisation self-efficacy (across groups) and performance time (r_s = -.10) and self-efficacy at the event and performance time (r_s = -.12) were small.

Perceived Control

For participants in the self-talk group, perceived control decreased from 8.46 ± 0.97 when Survey 1 was completed to 8.10 ± 1.08 (out of 10) at the event before the start. For participants in the control group, perceived control decreased from 8.66 ± 1.43 to 8.22 ± 1.15. The main effect of time did not reach statistical significance, $F(1, 17) = 2.72$, $p = .12$, $\eta_p^2 = 0.14$. The main effect of condition, $F(1, 17) = 0.10$, $p = .75$, $\eta_p^2 = 0.006$, and the interaction between time and condition, $F(1, 17) = 0.029$, $p = .87$, $\eta_p^2 = 0.002$, were not statistically significant. Spearman's rank-order correlations showed that negative correlations between pre-randomisation perceived control (across groups) and performance time (r_s = -.03) and perceived control at the event and performance time (r_s = -.10) were trivial and small, respectively.

Performance Expectations

As shown by the IQR values, expectations of performance improvement immediately before the ultramarathon were slightly higher in the self-talk group (out of 1-7, median = “5 – Agree”, IQR = 5-6) than the control group (median = “5 – Agree”, IQR = 4-5). The difference in changes in expectations, from pre- to post-intervention, between groups was not statistically significant (both medians = 0, both IQRs = -1-0), $U = 34.5$, $p = .58$.

Pre-Event Motivation

Pre-event motivation to participate did not differ significantly between groups (out of 0-4, both medians = “3 – Very much”, both IQRs = 3-4), $U = 45.0$, $p = .93$. Pre-event motivation to race against others was higher in the self-talk group (self-talk median = "2 – Somewhat", self-talk IQR = 1.5-3, control median = "1 – A little bit", control IQR = 1-2), but this difference did not reach statistical significance, $U = 25.5$, $p = 0.11$. Across groups, motivation to participate (median = 3, IQR = 3-4) was significantly greater than motivation to race against others (median = 2, IQR = 1-2) ($Z = -3.57$, $p < .001$).

Sport Emotions

Emotions and fatigue data are presented in Table 11. Between-condition differences in emotion change values were not statistically significant (p values ≥ .45). Increases in fatigue from pre-event to post-event were greater for the control group (2.00 ± 0.86) than the self-talk group (1.13 ± 1.27), but this difference did not reach statistical significance, $t(14) = -1.65$, $p = .12$.

Table 11

Sport Emotions and Fatigue of Finishers Before and After the Ultramarathon

	Pre-event		Post-event	
	Self-talk	Control	Self-talk	Control
Anxiety	1.43 ± 0.46	1.80 ± 1.04	0 ± 0	0.08 ± 0.14
Dejection	0.033 ± 0.082	0.18 ± 0.44	0.20 ± 0.40	0.40 ± 0.76
Excitement	2.33 ± 0.58	2.48 ± 1.00	2.13 ± 0.74	2.30 ± 1.19
Anger	0 ± 0	0.075 ± 0.24	0.25 ± 0.39	0.20 ± 0.26
Happiness	2.13 ± 0.77	2.30 ± 1.21	3.04 ± 0.66	3.20 ± 0.89
Fatigue	0.92 ± 0.61	0.50 ± 0.60	2.04 ± 0.89	2.50 ± 0.91

Note. Anxiety, dejection, excitement, anger, and happiness were measured using the Sport Emotion Questionnaire (M.V. Jones, Lane, Bray, Uphill, & Catlin, 2005). Fatigue was measured using the Brunel Mood Scale (Terry, Lane, Lane, & Keohane, 1999). Post-event values were reported 4 ± 5 days after finishing the event. Scores can range from 0 to 4. ± = mean ± standard deviation.

Ultramarathon Characteristics

Seven participants (33%) ran with other runners throughout the ultramarathon. The 14 participants who performed alone estimated that they ran alone for 40 ± 35% of the ultramarathon. As preparation for a 184-mile ultramarathon along the same route, eight participants (38%) carried some additional equipment with them, and three participants (14%) carried all additional equipment with them. Estimated equipment weights for these participants were 5.7 ± 1.2 kg. As displayed in Figure 9, ratings of perceived exertion, exercise-induced pain, and injury-related pain increased with distance covered during the ultramarathon.[3] Seventeen of 18 finishers (94%) experienced new or pre-existing injuries, including blisters, during the ultramarathon. Excluding injury, 18 of 21 participants (86%) encountered problems during the ultramarathon. By far, the most common problem, reported by 12 participants (57%), related to difficulty navigating in the dark.

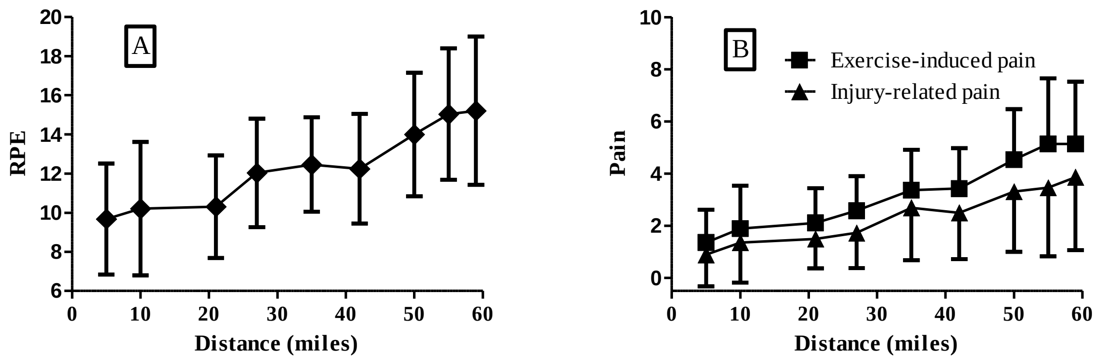

Figure 9. Mean ± standard deviation ratings of perceived exertion (RPE) (panel A) and ratings of pain (panel B) during the ultramarathon.

Performance

Eight of 10 participants in the self-talk group finished the ultramarathon, and 10 of 11 participants in the control group finished. The mean performance time of the self-talk group (818 ± 102 minutes) was 25 minutes (2.97%) faster than the control group (843 ± 84 minutes), $t(16) = 0.58$, $p = .28$, 90% confidence interval [-51, 102]. The effect size was small ($\Delta = 0.30$). The probability that the true effect is practically harmful/trivial/beneficial is 16.5/27.1/56.3%. For participants in this study, a 25-minute performance enhancement (if added to the finishing time of self-talk participants or deducted from the finishing time of control participants) would change their finishing positions by up to 14 places (mean ± standard deviation = 3 ± 3 positions [there were 26 finishers in the first year and 28 finishers in the second year]), and it would change the event winner in the first year of data collection.

Intervention Compliance

Participants generally complied with the interventions. Eight of 10 participants in the self-talk group reported that they had used the workbook to identify self-talk statements, and six participants submitted completed workbook logs. When participants used a five-point Likert scale to indicate if they used self-talk during the ultramarathon, the median response for participants in the self-talk group was “3 – Occasionally” (IQR = 3-4.5), and the median response for participants in the control group was “1 – Never” (IQR = 1-3). Nine of 11 participants in the control group reported that they had completed concentration grids, and eight participants submitted completed logs.

Intervention Contamination

No participants reported being told about the content of the other workbook.

Social Validity

Improvements in long-distance running performance were important to participants in both groups (out of 1-5, median = “4 – Agree”, IQR = 4-5), improvements in concentration were important to the control group (median = “4 – Agree”, IQR = 3-5), and the methods used to deliver the interventions were acceptable to participants in both groups (self-talk median = “4 – Agree”, self-talk IQR = 3.5-5, control median = “4 – Agree”, control IQR = 3-5). After the ultramarathon, changes in long-distance running performance were not considered to be significant by either group (self-talk median = “3 – Neither agree or disagree”, self-talk IQR = 2.5-3.5, control median = “3 – Neither agree or disagree”, control IQR = 3-3), and changes in concentration were not considered to be significant by the control group (median response = “3 – Neither agree or disagree”, IQR = 3-4). Seven of 10 participants in the self-talk group reported that using self-talk statements was helpful during the ultramarathon. Six months after the ultramarathon, changes in running performance were considered significant by the self-talk group (median = “4 – Agree”, IQR = 3-4). Changes in performance and concentration were not considered significant by the control group (median responses = “3 – Neither agree or disagree”, IQRs = 1-4).

Follow-Up of Intervention Use

Six months after the ultramarathon, eight of nine participants in the self-talk group reported using self-talk in training during the previous month (out of 1-5, median = “2 – Rarely”, IQR = 1.5-3), during their most recent event, which was 22 ± 7 weeks after the studied ultramarathon (median = “4 – A moderate amount”, IQR = 3.5-4), or during both training and events. Three of 11 participants in the control group reported using the concentration grid during the previous month (median = “1 – Not at all”, IQR = 1-2).

Qualitative Data

During training and endurance events, the self-talk group most commonly used self-talk to persevere or to push harder despite exertion (reported by eight of 10 participants) and to persevere despite stressors, namely getting lost, poor weather, low moments, or injury pain (reported by six participants). The reported use of self-talk was therefore consistent with the workbook instructions. The comments of six participants in the self-talk group indicated that that they had, to some extent, been using self-talk statements naturally or unsystematically before commencing the study.

Discussion

Psychological interventions such as PST consistently enhance endurance performance in non-competitive laboratory and field-based endurance tasks (Chapter 2). Few studies, however, have examined the effects of psychological interventions on performance in real-life endurance competitions, particularly using randomised, controlled experiments. The present study examined the effect of using motivational self-talk on performance in an ultramarathon. Participants who were taught motivational self-talk remotely using a workbook finished on average 25 minutes faster than a control group who were taught to use concentration grids to develop their concentration. Practically, the true effect size at the population level is unlikely (16.5% probability) to be harmful, possibly trivial (27.1% probability), and possibly beneficial (56.3% probability). Although self-talk possibly produced a performance enhancement that might benefit ultramarathon runners, additional data are required to draw firm conclusions. Additional data will be collected at the same ultramarathon in 2016.

Self-talk had a small, beneficial effect on ultramarathon performance ($\Delta = 0.30$). The wide confidence interval (90% CI [-51 minutes, 102 minutes]) can be attributed to the small sample size and the variation in participant performance times (Gardner & Altman, 1986). As in other competitions, participant performance times varied considerably because participants varied in their competitive standard. In addition, because of the nature of this ultra-endurance event, additional factors such as injury and navigation errors can also greatly influence performance. The beneficial effect of self-talk in the present study is consistent with experimental research that demonstrates that motivational self-talk enhances endurance performance in cycling time-to-exhaustion tests ($\Delta = 0.66$, Blanchfield, Hardy, de Morree, et al., 2014) and time trials ($\Delta = 0.39$, Barwood et al., 2015). Further, the motivational self-talk intervention in the present study was generally perceived favourably by participants. In particular, eight of 10 participants reported still using self-talk at the six-month follow-up, particularly in endurance events and to a lesser extent in training.

In the present study, learning to use motivational self-talk involved reading educational material, completing simple exercises, and practising self-talk during training runs. As the time investment for learning to use motivational self-talk is small (likely less than an hour), endurance athletes are encouraged to learn motivational self-talk. When the findings of the present study are interpreted in the context of existing research that shows motivational self-talk enhances endurance performance in controlled conditions (Barwood et al., 2015; Blanchfield, Hardy, de Morree, et al. 2014), this small time investment can be expected to, at best, enhance an endurance athlete's performance in competition or to, at worst, not affect their performance.

Many endurance athletes naturally talk to themselves during endurance events. For example, Van Raalte, Morrey, Cornelius, and Brewer (2015) found that 88% of marathon runners engaged in various types of self-talk that included associative, dissociative, motivational, goal-setting, incentive, mantra, and spiritual self-talk. In the present study, the intake interviews and the data of the control group suggested that, without receiving the self-talk workbook, participants were mostly unaware of using self-talk. During the intake interview, only two participants referred to using motivational self-talk statements as a psychological strategy during long-distance running events, and six of 11 participants in the control group reported using no self-talk (of any type) during the ultramarathon. Self-talk use during the ultramarathon was greater for participants in the self-talk group and, after using the workbook, six participants in the self-talk group commented that they previously used self-talk naturally or unsystematically. It is expected that the workbook used in this study encouraged participants to use self-talk more often than control participants, and also more systematically. Consistent with the workbook instructions, participants in the self-talk group reported using self-talk to persevere or to push harder despite exertion and to persevere when they encountered stressors (getting lost, poor weather, low moments, and injury pain).

In addition to examining the effect of motivational self-talk on ultramarathon performance, this study examined whether learning to use self-talk increased pre-event self-efficacy and perceived control. Self-efficacy, perceptions of control, and striving towards achieving goals influence challenge responses to upcoming competition (M. Jones et al., 2009). Participants in the present study strived to achieve mastery goals, which means that they typically strived to achieve absolute or intrapersonal competence (Conroy et al., 2003). In other words, participants strived to perform well relative to their own standards, rather than relative to others. This finding is consistent with earlier research that demonstrates that many ultramarathon runners attempt to achieve personal goals such as finishing or achieving a time, instead of placement goals (Acevedo et al., 1992; Simpson et al., 2014). In addition to striving for mastery goals, participants in the present study reported high self-efficacy and perceived control, independent of whether they were in the experimental or control group. These findings suggest that participants in this study typically experienced a challenge response, rather than a threat response, to the upcoming ultramarathon. Consistent with the Theory of Challenge and Threat States in Athletes (M. Jones et al., 2009), this challenge response was accompanied by positively-toned emotions. Specifically, emotional states before the event start were characterised by excitement, happiness, and some anxiety, and emotional states after finishing were characterised by excitement and happiness. Self-efficacy and perceived control values indicated that participants believed that they could cope with the event demands and achieve their goal (i.e., self-efficacy) and that they perceived themselves as having sufficient control over how they responded to the event demands (i.e., perceived control). The self-talk intervention did not enhance these perceptions. Further, correlations between self-efficacy and perceived control values before the event start and performance time were trivial to small. These correlations indicate that there was little association between self-efficacy and perceived control and performance time in this particular ultramarathon. This may be because most participants in the present study reported high self-efficacy and perceived control (i.e., scores were homogeneous). Self-efficacy and perceived control during ultramarathons, such as after encountering stressors, might have a stronger association with performance than self-efficacy and perceived control before the event start.

Few studies examining the effects of psychological interventions on endurance performance have included a placebo control group (Chapter 2). It is therefore difficult to determine the extent to which improvements in endurance performance can be attributed to enhanced expectations of performance improvement. In the present study, participants assigned to the control group were given an alternative control treatment. Alternative control treatments are similar in duration, perceived value, and procedure to the experimental treatment, but they target different outcomes (W. Borg, 1984). Providing control-group participants with a traditional placebo, such as an inert solution that is described favourably, would not have involved the same time commitment as the self-talk workbook. Participants in the control group might therefore have sought the benefits of both interventions—referred to as contamination—which could have reduced the observed effect of the self-talk intervention. Further, unlike control groups who receive no intervention or a traditional placebo intervention, similar intervention demands are placed on alternative control groups as the experimental group (e.g., time demands, completion of logs as evidence of compliance), which can reduce bias associated with study dropouts (W. Borg, 1984). Although a traditional placebo control was not used, the possible effects of self-talk on performance are unlikely to be attributable to a placebo effect because expectations of improved performance were measured and were similar between groups (Boot et al., 2013).

The alternative control treatment involved practising concentration grids to develop concentration. This intervention was chosen because it was similar in duration and procedure to the self-talk intervention, and it targeted concentration rather than performance. It is questionable, however, whether this control intervention had similar perceived value to the self-talk intervention. Although participants in the control group reported that improvements in concentration were important to them, only three of 11 participants in the control group were still using the concentration grid at the six-month follow-up. In contrast, eight of 10 participants in the self-talk group reported still using self-talk. The self-talk group might therefore have valued the content of their workbook more. Further, experimental research suggests that the concentration grid might not be efficacious at improving concentration when it is used in isolation, rather than as part of a PST package, without extensive practice (Greenlees, Thelwell, & Holder, 2006). PST interventions involving goal setting, imagery, and relaxation could be expected to have similar perceived value to a self-talk intervention. As goal setting, imagery, and relaxation interventions consistently enhance endurance performance (see Chapter 2), these interventions were not incorporated into the alternative control treatment. Finally, although the alternative control treatment targeted concentration rather than performance, an improvement in concentration could potentially improve ultramarathon performance; that is, the targeted outcomes are somewhat related (cf. W. Borg, 1984). When designing the concentration workbook, care was therefore taken not to suggest performance-relevant cues that participants could apply the concentration grid to during the ultramarathon; omitting this information might have detrimentally affected the perceived value of the alternative control treatment. Although using the concentration workbook as an alternative control treatment has limitations, no participants in the control group reported being aware of the content of the self-talk intervention. This suggests that the alternative control treatment prevented contamination and therefore served a valuable purpose. Researchers conducting psychological intervention research are encouraged to consider other ways of including an alternative control treatment, in order to reduce sources of bias that could influence the drawn conclusions.

The intake interviews were conducted before participants were allocated to experimental and control groups. Further, once participants had received their workbook, the researcher did not speak with participants about their particular workbook by video call or telephone. Instead, participants were able to ask questions using an online survey, and these questions were answered by email. These decisions were made to prevent biasing the results by systematically introducing expectation effects. This intervention format, however, is unrepresentative of how the intervention would be delivered in an applied setting. Further, additional, personalised support from a sport psychologist could have helped participants to make better use of motivational self-talk and therefore increase the size of the intervention effect. Indeed, the somewhat artificial nature of the intervention could explain why expectations of performance improvement slightly decreased for participants in both conditions. Nevertheless, the intervention appeared to benefit ultramarathon performance. These findings therefore suggest that PST interventions can be efficacious when delivered remotely (Richards, Thorogood, Hillsdon, & Foster, 2013) using a workbook and email. PST interventions delivered without in-person contact could be a cost-effective way to make sport psychology accessible to a greater number of athlete consumers, who might struggle to attend regular meetings with a sport psychologist due to time and financial commitments (Weinberg, Neff, et al., 2012). Additional data are required, however, before firm conclusions can be drawn about the effects of delivering self-talk in this particular format.

In addition to reading the workbook and completing exercises, participants were encouraged to practise self-talk during training runs. Although self-talk interventions that do not involve practise can enhance performance (e.g., Schüler & Langens, 2007), practising self-talk leads to greater effects on sport performance (Hatzigeorgiadis et al., 2011). In the present study, the researchers aimed to give participants at least two weeks to practise self-talk, because practising motivational self-talk for two weeks can have a substantial effect on endurance performance (Blanchfield, Hardy, de Morree, et al., 2014). Logistical aspects of recruiting participants through an event gatekeeper, however, made it difficult to control the amount of time available for practising self-talk. It is possible that allowing additional time to practise self-talk could have led to self-talk having a greater effect on performance. For example, if using motivational self-talk becomes more automatic through practice (Zinsser, Bunker, & Williams, 2001), then endurance athletes might use motivational statements more frequently during events or they might be more likely to use motivational statements to cope with stressors that could undermine their motivation. In addition, the deliberate, conscious control of self-talk earlier in the process of learning to use self-talk statements could be mentally fatiguing, which could counter some of the beneficial effects of using self-talk by increasing perception of effort or undermining decision making (Baumeister et al., 1998; Marcora et al., 2009). As the dose-response relationship between self-talk practice and performance is unclear (Hatzigeorgiadis et al., 2011), future research could examine whether there is an optimal amount of self-talk practice for enhancing endurance performance.

Conclusions

This study examined the effect of using motivational self-talk on performance in an ultramarathon. Ultramarathon runners who were taught motivational self-talk remotely using a workbook finished on average 25 minutes faster ($\Delta = 0.30$) than runners who were taught to use concentration grids to develop their concentration. There was also evidence that most participants were still using self-talk six months after the ultramarathon, particularly in endurance events and to a lesser extent in training. The motivational self-talk intervention did not affect pre-event self-efficacy or perceived control, however. Although self-talk possibly produced a performance enhancement that might benefit ultramarathon runners, additional data are required to draw firm conclusions. Additional data will therefore be collected at the same ultramarathon in 2016.

Notes

[1] A Spearman's rank-order correlation showed that the negative correlation between estimated $\dot{V}O_{2max}$ and performance time in the ultramarathon was trivial (r_s = -.06).

[2] The event organisers used different maps during the second year of data collection, and it was not feasible to print scales on the maps during the second year.

[3] All event competitors carried GPS tags that gave real-time information on their progress. These GPS tags provided information on each participant’s pacing. GPS data were only available for the second year. There was insufficient GPS and self-report data to compare ratings of perceived exertion and pain, relative to pace, between conditions.

Chapter 6

General Discussion

Summary of Main Findings

With an emphasis on endurance sports, the main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance. By doing so, this thesis has the potential to inform evidence-based application of psychology in endurance sports. There were three main research aims. First, this thesis aimed to synthesise research conducted to date on the psychological determinants of endurance performance. Second, this thesis aimed to inform the design of performance-enhancement psychological interventions for endurance sports. Third, this thesis aimed to examine the effect of a psychological skills training (PST) intervention on performance in a real-life endurance event. Four studies were conducted to achieve these aims.

The first aim of the thesis was to synthesise research conducted to date on the psychological determinants of endurance performance. Although research has accumulated during the last 50 years—beginning with Wilmore (1968)—demonstrating that psychological interventions affect endurance performance, Chapter 2 is the first systematic literature review of the psychological determinants of endurance performance. Specifically, this systematic review identified practical psychological interventions that enhance endurance performance, and it identified additional psychological determinants of endurance performance. Learning psychological skills such as self-talk, imagery, and goal setting consistently enhanced endurance performance. In addition, verbal encouragement and head-to-head competition enhanced endurance performance, and mental fatigue undermined endurance performance. This systematic review offered implications for theory, future research, and psychology application, based on research evidence.

The second aim of the thesis was to inform the design of performance-enhancement psychological interventions for endurance sports. This aim was addressed through two studies (Chapter 3 and Chapter 4). Chapter 3 used focus group interviews with recreational runners, cyclists, and triathletes to identify psychological demands that are commonly experienced by endurance athletes. Away from the competitive environment, endurance athletes described substantial time investments and sacrifices associated with participation in endurance sports that are unusual for recreational populations of athletes. In addition, they described concerns they had about optimising their training, a lack of commitment to training sessions, and unpleasant exercise sensations that they must push through during training to improve their performance in events. Preceding events, endurance athletes described finding pre-event logistics stressful, worrying that something might go wrong before the start, and the detrimental consequences of something going wrong. During events, endurance athletes described unpleasant exercise sensations, difficult pacing decisions, and stressors that had negative effects on their emotions, motivation, and concentration. Although preceding studies have highlighted the psychological demands of specific endurance sports and distances, none have included athletes of different endurance sports, distances, or competitive levels and examined common psychological demands. Interventions that help endurance athletes to cope with these psychological demands could enhance performance in endurance events.

Chapter 4 also addressed the second aim of the thesis, which was to inform the design of performance-enhancement psychological interventions for endurance sports. Although people frown more when they perceive high levels of effort, such as during endurance performance (de Morree & Marcora, 2012), a substantial volume of research on the facial feedback hypothesis (Niedenthal et al., 2005) suggests that frowning might also modulate (amplify or soften) perception of effort. If frowning modulates perception of effort, then interventions targeting frowning could offer a novel method of enhancing endurance performance. Applying predictions of the facial feedback hypothesis and the psychobiological model of endurance performance, Chapter 4 investigated whether intentionally frowning throughout a cycling time-to-exhaustion test increased perception of effort and, consequently, reduced time to exhaustion. Contrary to hypotheses, frowning did not affect perception of effort or time to exhaustion, which suggests that frowning may not modulate perception of effort during severe-intensity endurance performance. In addition, frowning did not influence affective states experienced during performance or after exhaustion. Although additional research using different methods would allow firmer conclusions to be drawn, these findings suggest that novel, psychologically-informed interventions that target the expression of a frown would be unlikely to offer an efficacious method of enhancing performance in endurance sports.

Finally, the third aim of the thesis was to examine the effect of a PST intervention on performance in a real-life endurance event. Although a considerable amount of research demonstrates that psychological interventions enhance endurance performance in non-competitive, laboratory and field-based endurance tasks (Chapter 2), no studies published to date have examined the effect of a PST intervention on performance in an endurance event using a randomised, controlled experiment. Chapter 5 examined the effect of a motivational self-talk intervention on performance in a 60-mile, overnight ultramarathon. Contrary to hypotheses, learning to use motivational self-talk intervention did not affect pre-event self-efficacy or perceived control. Nevertheless, participants in the self-talk group finished on average 25 minutes faster than participants in a control group, and eight of 10 participants continued to use self-talk after their commitment to the study. Although the performance times indicated that motivational self-talk possibly produced a performance enhancement that might benefit ultramarathon runners, additional data will be collected at the same ultramarathon in 2016 to draw firmer conclusions.

Theoretical Implications

Few studies conducted to date on the psychological determinants of endurance performance were informed by psychological theory. Of the 46 studies included in the systematic literature review (Chapter 2), only three studies examining practical psychological interventions (Barwood et al., 2015; Blanchfield, Hardy, de Morree, et al., 2014; Post et al., 2012) and eight studies examining additional psychological determinants (Blanchfield, Hardy, & Marcora 2014, Experiments 1 and 2; Hodgins et al., 2006; MacMahon et al., 2014; Marcora et al., 2009; M. Miller, 1993; Pageaux et al., 2014; Wagstaff, 2014) were clearly informed by psychological theory (24% overall). Of these 11 studies, seven studies were informed by the psychobiological model of endurance performance, which demonstrates that few psychological theories have been applied to endurance performance. Further, only 22 of the 46 included studies (48%) measured psychological variables. The intervention-performance psychological mechanism was therefore unclear in many studies. For example, post-hypnotic suggestion (Jackson et al., 1979), goal setting (e.g., Theodorakis et al., 1998), head-to-head competition (e.g., Corbett et al., 2012), and verbal encouragement (e.g., Moffatt et al., 1994) affected endurance performance, but the effects of these interventions on psychological variables were not measured. Theoretically-informed studies that measure psychological mediating variables are therefore encouraged to illuminate intervention-performance psychological mechanisms.

Psychobiological Model

Studies included in the systematic literature review supported the psychobiological model of endurance performance when they included psychological mediating variables. Interventions such as motivational self-talk (e.g., Blanchfield, Hardy, de Morree, et al., 2014) that reduced perception of effort enhanced endurance performance, and interventions such as mental fatigue (e.g., Marcora et al., 2009) that increased perception of effort detrimentally affected endurance performance. These findings are consistent with research in the broader sport science literature. Interventions that reduce perception of effort such as increased oxygen supply (Tucker et al., 2007), caffeine (Ivy et al., 2009), and modafinil (Jacobs & Bell, 2004) enhance endurance performance, whereas interventions that increase perception of effort such as muscle fatigue (de Morree & Marcora, 2013) or sleep deprivation (Oliver et al., 2009) detrimentally affect endurance performance.

The psychobiological model predicts that interventions that increase potential motivation will enhance endurance performance, and interventions that decrease potential motivation will detrimentally affect endurance performance (Marcora et al., 2008). A person's potential motivation is determined by factors traditionally associated with motive strength such as a person's needs, potential outcomes of an instrumental behaviour, and the perceived probability that a successfully-executed behaviour will satisfy a need or produce a desired outcome (Brehm & Self, 1989). Psychological interventions such as verbal encouragement (e.g., Moffatt et al., 1994), head-to-head competition (e.g., Corbett et al., 2012), goal setting (e.g., Theodorakis et al., 1998), and performing in front of a person of the opposite sex (Jung et al., 2009) could be expected to increase a person's potential motivation, and these psychological interventions have been shown to enhance endurance performance. Nevertheless, these studies did not explicitly examine the effects of interventions on potential motivation, or the effect of potential motivation on endurance performance.

Methodological issues make it difficult to demonstrate that potential motivation is a determinant of endurance performance. If participants in experimental studies are highly motivated and willing to offer their maximum effort, then it may be unfeasible to increase potential motivation. For example, an incentive of $100 did not improve the time-trial performance of regional-level cyclists (Hulleman et al., 2007). This incentive may not have increased the cyclists' potential motivation, particularly because the cyclists were aware of performance records achieved in that laboratory and could have competed against them. In addition, social desirability bias—the "tendency of individuals to present themselves in the most favorable manner relative to prevailing social norms and mores" (King & Bruner, 2000, p. 80)—could make it difficult to measure the effects of interventions on potential motivation. Potential motivation can be measured using a pre-performance motivation questionnaire. However, participants may consistently report high levels of motivation to present themselves favourably. Potential motivation can also be captured by a participant's highest rating of perceived exertion (RPE). However, participants may report ceiling RPE values to present themselves as offering their best effort, particularly because researchers typically ask them to offer their best performance (e.g., Chapter 4). Researchers could take steps to reduce social desirability when examining the predictions of the psychobiological model in experimental research. For example, participants could submit a completely-anonymous (i.e., without a participant code or other identifying information) (Joinson, 1999; King & Bruner, 2000), pre-performance motivation questionnaire and a completely-anonymous, written RPE value immediately after exhaustion that reflected their perception of effort at exhaustion. For example, these questionnaires could contain a code that permits data analysis without compromising anonymity, they could be submitted into a pillar box, and a different researcher could collect and analyse the data following study completion. Nevertheless, social desirability bias is a pervasive problem when collecting self-report data, and there is unlikely to be a simple solution to this problem (Nederhof, 1985).

According to the psychobiological model, potential motivation and perception of effort are the ultimate determinants of endurance performance. In other words, all interventions that affect endurance performance do so because they affect either potential motivation or perception of effort (Marcora, 2010b). This is captured in Figure 10.

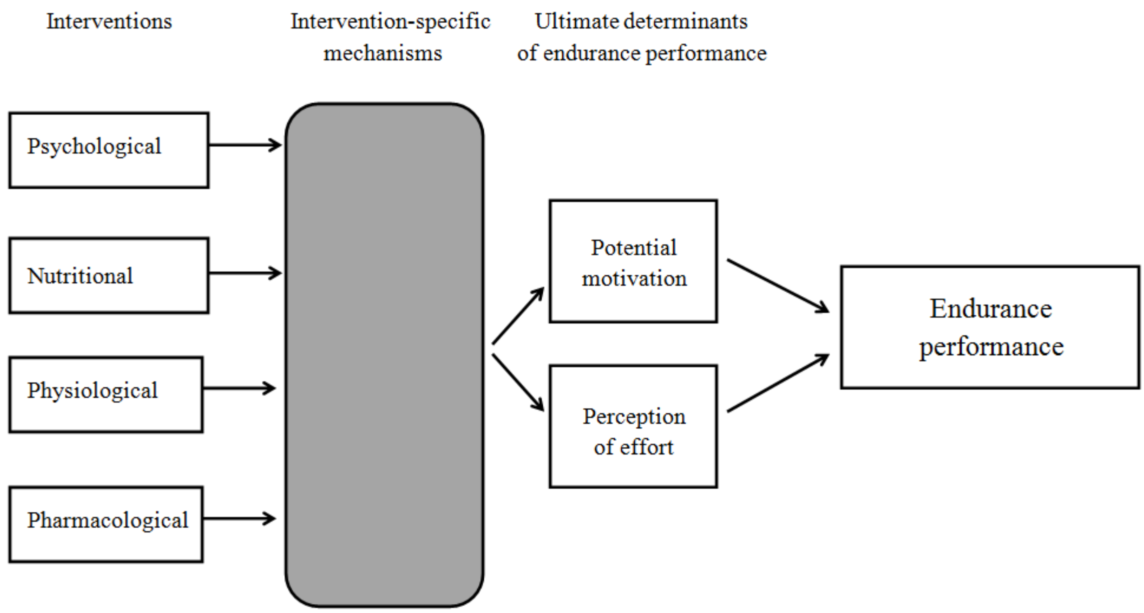

Figure 10. Diagram demonstrating how interventions affect endurance performance in the psychobiological model.

Potential motivation and, in particular, perception of effort are therefore the psychological constructs that are most emphasised in the psychobiological model. The psychobiological model, however, does not identify the psychological mechanisms that cause psychological interventions to influence potential motivation or perception of effort. For example, it is currently unclear why PST interventions such as motivational self-talk affect perception of effort (see Blanchfield, Hardy, et al., 2014; Barwood et al., 2014). PST interventions may be beneficial for endurance performance because they increase self-efficacy (M. Miller, 1993) or because they influence an athlete’s perceived (i.e., secondary appraisal) or actual ability to cope with encountered stressors (Chapter 3). Although these hypothetical effects on self-efficacy, appraisal, and coping could ultimately enhance endurance performance by increasing potential motivation or reducing perception of effort, these psychological mechanisms would nevertheless play a key role in determining endurance performance. Further, until these psychological mechanisms are clarified, the psychobiological model could have limited utility to sport psychology practitioners, because it provides limited theoretical guidance that practitioners can use to reduce perception of effort, and because potential motivation is likely high in many competitive athletes. Considering the psychobiological model in conjunction with additional psychological theories, such as self-efficacy theory or cognitive-motivational-relational (CMR) theory, could therefore offer a more comprehensive explanation of how psychological interventions influence endurance performance and facilitate application of research for enhancing endurance performance. For example, coaches and practitioners could use interventions to target the sources of self-efficacy (e.g., vicarious experience) in order to increase self-efficacy, which may reduce perception of effort and enhance endurance performance.

Finally, it is plausible that, in addition to potential motivation and perception of effort, self-efficacy and concentration directly affect endurance performance. Motivational intensity theory (Brehm & Self, 1989), which informed the psychobiological model, proposes that the amount of effort that a person offers is influenced by whether they believe that success in the task is possible. If a person perceives task success as impossible, then they are likely to offer low effort because the expenditure of effort will yield no benefit. People performing endurance tasks are likely to be pursuing performance goals and, applying this prediction, they may withdraw effort when they perceive goal achievement as impossible. Indeed, data shows that people performing endurance tasks involving an incremental workload are much more likely to quit the test at the beginning of a new level (Lorimer & Babraj, 2013; Wilkinson et al., 1999); this may be because they believe that they cannot reach the next level and that continued effort will not be justified by the achievement of another performance goal. A person’s efficacy magnitude (their beliefs about the level of performance that they can achieve) and efficacy strength (their degree of certainty that they can achieve a particular level of performance) could therefore play an important role in endurance performance through their effect on a person's task effort. In addition, concentration—defined as "the ability to focus mental effort on what is most important in any situation while ignoring distractions" (Lavallee, Kremer, Moran, & Williams, 2004, p. 115)—could also directly affect endurance performance. During a time trial, concentration may allow an endurance athlete to consciously control their pacing to optimise the increase in their perception of effort over time; in contrast, distraction by task-irrelevant internal (e.g., thoughts about mistakes) or external cues (e.g., the crowd) may cause pacing to become more automatic, and perception of effort may increase faster or slower than is optimal. Concentration could also facilitate application of good technique, navigation, and tactical decision making during head-to-head competitions. As highlighted in Chapter 3 (qualitative study), endurance athletes encounter a range of stressors that can have detrimental effects on their concentration and that could therefore influence their performance.

Pain

Pain emerged as an important aspect of endurance performance in Chapter 3 (qualitative study) and Chapter 5 (ultramarathon study). In Chapter 3, recreational endurance athletes reported that pain and discomfort were psychological demands experienced in training and competition. This finding was consistent with other qualitative studies that have identified pain and discomfort as demands when participating in endurance events (Brick et al., 2015; Crust et al., 2010; Hollander & Acevedo, 2000; Holt et al., 2014; Kress & Statler, 2007; J. M. Schumacher et al., 2016; Simpson et al., 2013, 2014). The athletes in Chapter 3 recognised that they need to persevere through this pain and discomfort to achieve physiological adaptation from training or a desired outcome, such as a personal best time, from an event. In Chapter 5, exercise-induced pain (defined as aching and burning muscles) and injury-related pain were measured. Figure 9 (p. 180) demonstrates that, in addition to effort, the ultramarathon runners experienced high amounts of exercise-induced pain and injury-related pain during the ultramarathon, and the amounts of pain increased over time.

As pain is an important psychological demand in endurance events, endurance athletes who can tolerate pain could be expected to have an advantage over their competitors. Indeed, there is data that suggests that pain tolerance is important for performance in sports where athletes experience pain while racing. Although they did not focus on endurance-distance events, Scott and Gijsbers (1981) found that national-level swimmers demonstrated substantially greater pain tolerance (approximately 48% greater) in an ischaemic pain test than club-level swimmers, who demonstrated greater pain tolerance (approximately 27% greater) than people who did not have experience competing at sport. The pain thresholds—points of the test at which participants began to experience pain—were similar between groups, which indicated that the swimmers did not find the pain test less painful but were instead better at tolerating the pain. Further, the pain tolerance of national-level swimmers varied across the stage of the competitive season, with greater pain tolerance during the peak of the training season, which indicates that systematic exposure to intense pain in training could increase tolerance of it. In addition, a recent study demonstrated that pain tolerance when cycling at a fixed RPE of 16 (corresponding to a verbal anchor between “hard” and “very hard”) predicted the performance of recreational exercisers in a 16.1 kilometre time trial (Astokorki & Mauger, 2016). It was suggested that the ability to tolerate greater amounts of pain allowed faster performers to maintain high power outputs during the time trial.

There is also evidence that endurance athletes are more tolerant of pain than normally-active controls, although it is unclear whether endurance athletes have higher pain thresholds (Tesarz, Schuster, Hartmann, Gerhardt, & Eich, 2012). For example, participants of the TransEurope FootRace (4,487 kilometres over 64 days without resting days) reported less pain during a three-minute cold-pressor test, which required participants to immerse their hand in ice-cold water, than matched controls who did not have recent experience in endurance events. They were also more likely to tolerate the pain for the full three minutes (Freund et al., 2013). In addition, marathon runners had higher pain tolerance (approximately 40% higher) and pain thresholds (approximately 60% higher) than matched non-runners in a potassium iontophoresis procedure, which involves the delivery of potassium ions through the skin by passing an electric current through a potassium chloride solution. Marathon runners were also more confident in their ability to deal with the pain (approximately 19% higher), and this confidence accounted for 40% of the difference in pain tolerance (Johnson, Stewart, Humphries, & Chamove, 2012). It may be that endurance athletes have learned to tolerate pain through their involvement in endurance sports or, alternatively, that predisposed high pain tolerance helps them to perform over long distances and at high intensities.

As pain is an important psychological demand in endurance events, psychological interventions that increase an endurance athlete's pain tolerance may enhance their performance. Surprisingly, no located studies have examined the effects of PST on the intensity of exercise-induced muscle pain experienced during endurance performance or the duration that performers tolerate a fixed (or "clamped") amount exercise-induced pain. For example, no studies included in the systematic literature review (Chapter 2) measured pain as a potential mediating variable. There are studies, however, that have examined the effects of psychological strategies on tolerance of other types of pain. For example, rowers, cyclists, and triathletes who were taught to use psychological skills (relaxation, self-talk, and attention control) using a stressinoculation training framework increased their tolerance of pain and discomfort experienced during a wall-sit muscular-endurance task (Whitmarsh & Alderman, 1993).

The role of pain in determining endurance performance is downplayed by the psychobiological model of endurance performance. According to the psychobiological model, perception of effort is the main factor that influences pacing decisions and performance in an endurance event (Pageaux, 2014). Mauger (2014), however, argued that pacing is a complicated process influenced by numerous factors, not just perception of effort. Specifically, Mauger argued that exercise-induced muscle pain and discomfort also contribute to pacing decisions and endurance performance, particularly during high-intensity exercise. Mauger proposed that endurance athletes are only willing to endure a certain amount of pain and discomfort, and they adjust their pace to regulate their experienced pain and discomfort. This is a similar proposal to the psychobiological model, but it suggests that athletes adjust their pace to control the increase in multiple exercise-related sensations (not just perceived effort). The intensity of pain that an athlete will tolerate is proposed to depend on the duration that they must tolerate this pain. For example, cyclists might tolerate intense pain during a sprint finish or when other cyclists are setting a fast pace in a road race (Kress & Statler, 2007) because they know that they only need to tolerate the pain for a short duration. Conversely, they might terminate a time-to-exhaustion test when enduring less pain for a longer period of time without respite. The findings of chapter 3 and other qualitative studies (e.g., Holt et al., 2014; Kress & Statler, 2007; Simpson et al., 2014) suggest that endurance athletes experience various exercise-induced sensations during training and competition, such as exercise-induced muscle pain, injury-related pain, heavy breathing, and cramping discomfort, and that a combination of these exercise-induced sensations make it difficult for the athlete to continue. It is difficult, however, to isolate the contributions of perceived effort, pain, and discomfort to pacing and endurance performance. As demonstrated in Figure 9 (p. 180), perceived pain and effort typically increase alongside one another, and some interventions that reduce pain, such as paracetamol, also reduce perception of effort (Mauger et al., 2010). Nevertheless, recent data indicates that the contributions of perception of effort and exercise-induced muscle pain to endurance performance can be dissociated (Astokorki & Mauger, 2016). An additional consideration is that measures of perception of effort often use inappropriate definitions, which means that ratings of perceived effort in some studies could also reflect perceived pain and discomfort (Abbiss et al., 2015; Marcora, 2009; Mauger, 2014). Moreover, endurance athletes in Chapter 3 and other qualitative studies (e.g., Simpson et al., 2014) could have used the words “pain” and “hurt” to capture exercise-induced sensations other than exercise-induced muscle pain or injury-related pain, such as the strenuous of continuing or their heavy breathing (i.e., perceived effort). Nevertheless, the qualitative data reported in Chapter 3 and other studies could indicate that various exercise-induced sensations contribute to pacing decisions and endurance performance. Including perceived pain as a standard perceptual measure in future research (Mauger, 2014), and defining perceived effort and pain carefully (see Pageaux, 2016), could clarify the roles that perceived pain, perceived effort, and other exercise-induced sensations play in determining pacing and endurance performance at different exercise intensities and over various distances.

Emotions

Theories of emotion and emotion regulation have implications for endurance performance. Chapter 3 (qualitative study) illuminated stressors that are commonly experienced by recreational endurance athletes away from the competitive environment (e.g., finding time to train), before an endurance event (e.g., arriving late), and during an event (e.g., unfavourable weather). These stressors were associated with self-reports of feeling stressed and negatively-toned emotions, such as frustration, guilt, anxiety, and discouragement. Applying CMR theory (Lazarus, 1999, 2000), the endurance athletes' self-reports of negatively-toned emotions indicated that they appraised the stressors as endangering their sport or family goals or their core values, which may have been spending time with family, participating in an event, or attaining a time or outcome in an event. Further, the negatively-toned emotions indicated that the athletes believed that their coping options were insufficient for the experienced stressors (Martinent & Ferrand, 2015; Uphill & Jones, 2007). Consistent with research conducted on other sports (Dugdale et al., 2002; Martinent & Ferrand, 2009; Vast et al., 2010), the athletes' negatively-toned emotions appeared to detrimentally affect their motivation and concentration. For example, the endurance athletes reported focusing on task-irrelevant cues and reduced motivation to persevere after encountering stressors during endurance events. Negatively-toned emotions, however, can also have beneficial effects on performance (Martinent & Ferrand, 2009). If an athlete believes that they have the resources to control and cope with their emotions, then they can re-appraise their emotions in a way that increases their motivation, effort, and concentration (Fletcher et al., 2006; Neil, Hanton, & Mellalieu, 2013; Neil, Hanton, Mellalieu, & Fletcher, 2011). In other words, they can interpret a negatively-toned emotion in a way that is facilitative, rather than detrimental, to their performance. Cognitive appraisals therefore appear to play an important role in determining performance in endurance sports. If an endurance athlete believes that they have sufficient coping resources, then they could be expected to experience less negatively-toned emotions before and during performance, or they could use these emotions to their advantage. Psychological skills training could therefore benefit endurance athletes by influencing their perception of available coping resources or by helping them to re-appraise negatively-toned emotions to enhance their motivation, effort, and concentration.

The process model of emotion regulation (Gross, 1998) also has implications for endurance performance. Endurance athletes use a broad selection of strategies to regulate their emotions before and during performance (e.g., Stanley et al., 2012). These emotions could include anxiety, guilt, frustration, and discouragement (Chapters 3 and 5). Research on the process model suggests that the specific emotion-regulation strategies that endurance athletes use could affect their performance. The process model proposes that emotions can be regulated at five points in the emotion generative process, and emotion-regulation strategies that act at the different stages have different profiles of consequences. For example, re-appraisal involves changing the way a situation is construed to decrease its emotional impact, and it occurs earlier in emotion generative process than suppression, which involves inhibiting the outward signs of experienced inner feelings. Experimental and observational studies demonstrate that re-appraisal leads to more desirable outcomes than suppression (Gross, 2002). For example, only re-appraisal leads to reduced experience of negatively-toned emotions, and suppression places a greater demand on finite cognitive resources. Re-appraisal is therefore more effective under some circumstances. For example, re-appraising adversity encountered during an event (e.g., unfavourable weather and surface conditions) as an additional challenge to overcome could lead to superior cognitive performance (e.g., navigation, pacing decision making) compared to suppression. Further, using emotion suppression to cope with negatively-toned emotions experienced before performance is detrimental to endurance performance because it increases perception of effort (Wagstaff, 2014). As discussed in the following section (Future Research), research is encouraged that examines the effects of emotion-regulation strategies that are commonly used by endurance athletes before and during endurance events.

Future Research

Research examining psychologically-informed methods of enhancing endurance performance should be informed by theory and measure mediating and moderating variables. Theoretically-informed research that measures mediating variables could offer greater clarity on the intervention-performance psychological mechanisms, and researchers and practitioners could then target these mechanisms using interventions. Theoretically-informed interventions might therefore produce greater or more consistent effects on endurance performance (Michie & Prestwich, 2010). Little is also known about whether participant and sport characteristics, such as competitive level, competitive distance, or achievement-goal orientation, influence the effects of psychological interventions. Examining moderating variables could shed light on whether certain interventions are particularly beneficial for specific groups of endurance athletes, and this evidence base could be used to optimise the effects of psychological interventions.

Future research could compare the effects of different PST interventions and examine whether the effects of PST interventions are additive. Goal setting (e.g., Tenenbaum et al., 1999), imagery (Post et al., 2012), self-talk (e.g., Blanchfield, Hardy, de Morree, et al., 2014), and using a combination of multiple psychological skills (e.g., Barwood et al., 2008) have been shown to enhance endurance performance; no studies, however, have compared the effects of these interventions on endurance performance. It is therefore unclear whether some PST interventions have greater effects on endurance performance than others. It is also unclear whether interventions that teach multiple psychological skills have greater effects on endurance performance than interventions that teach one psychological skill. Research conducted on sports performance more generally suggests that combined interventions may have greater effects, but firm conclusions have not been drawn (Hatzigeorgiadis et al., 2011; Papaioannou, Ballon, Theodorakis, & Auwelle, 2004). Teaching multiple psychological skills is likely to require a greater time and financial investment from an athlete, but it may not lead to greater improvements in performance. As endurance athletes may have restricted time available (Chapter 3), time-efficient interventions are desirable. Research comparing the effects of different PST interventions is therefore encouraged.

Research examining the effects of psychological interventions should, when feasible, examine performance when participants are in motivated performance situations representative of real-life competition. Researchers could use external motivators such as head-to-head competition and verbal encouragement, which are typically present during endurance competition. People typically perform better in competitive endurance tasks (e.g., Corbett et al., 2012) and when they receive verbal encouragement (e.g., Moffatt et al., 1994), and these factors might influence endurance performance through the same psychological mechanisms as the examined intervention (e.g., by increasing motivation). Further, endurance performers are likely to appraise competitive situations differently from non-competitive situations. Performers could think that there is a significant goal at stake during competitive experimental trials (e.g., outperforming others), and they could therefore experience similar emotional responses during their performance as they might during a real-life endurance event. Results of studies that measure endurance performance in motivated performance situations could therefore be more likely to generalise to real-life competition; that is, they would have greater ecological validity. To include head-to-head competition in a consistent manner, a computer-generated avatar that is an accurate (Corbett et al., 2012) or slightly superior (Stone et al., 2012) representation of an earlier performance could be described as representing the performance of a competitor of similar ability. Verbal encouragement should be delivered by a person who is blinded to the participant's condition to ensure that it is delivered consistently across conditions.

Theoretically-informed research could examine the effects of different emotion-regulation strategies that are used before and during endurance events. Some emotions are more pleasant than others, and the emotions experienced by athletes can influence their motivation, concentration, and performance (Chapter 3; Dugdale et al., 2002; Martinent & Ferrand, 2009; Vast et al., 2010). It is therefore unsurprising that athletes use a range of strategies to maintain desirable emotions and to change undesirable emotions (Andrew M. Lane, Beedie, Jones, Uphill, & Devonport, 2012). Although research has shed light on what emotion-regulation strategies endurance athletes use (e.g., Stanley et al., 2012), little experimental research (cf. Andrew M. Lane et al., 2016; Wagstaff, 2014) has examined the effects of using different emotion-regulation strategies before or during endurance performance. This is important because athletes commonly use emotion-regulation strategies that act at different stages of the emotion generative process (Andrew M. Lane et al., 2012), and strategies that act at the different stages have different profiles of consequences (Gross, 2002). Research could therefore examine the effects of emotion-regulation strategies that are commonly used before and during endurance events on important variables such as perception of effort, decision making, and performance. Research examining the effects of thought stopping, which is commonly taught by sport psychologists (e.g., Sheard & Golby, 2006) but involves thought suppression, is particularly encouraged, because suppressive strategies can increase perception of effort (Wagstaff, 2014). It is therefore plausible that thought stopping is detrimental to endurance performance, but research has not examined this.

Studies that have examined the effects of PST on endurance performance often included goal setting as an intervention component (e.g., Barwood et al., 2008; Patrick & Hrycaiko, 1998; Tenenbaum et al., 1999; Thelwell & Greenlees, 2001, 2003). Participants in these studies were typically taught to set various types of goal (e.g., short-term and long-term goals; process, performance, and outcome goals) to facilitate immediate or short-term performance improvements. Mediating variables were not typically measured, which means that the intervention-performance mechanism cannot be determined. It is likely, however, that the performance enhancements occurred through a psychological mechanism, such as through increased performance motivation (Bandura & Cervone, 1983). Goal setting was not incorporated into participants' training practices, and so the interventions would not have influenced the fitness or technique of the participants. For example, university students cycled for 12% longer in a second incremental cycling test when, immediately before this cycling test, they set a goal to improve their performance and then received feedback on the lapsed performance time (Theodorakis et al., 1998). High-school cross-country runners also improved their performance times by approximately 8% over the course of a month when they were pursuing weekly improvements in their times, without alterations to their training programme (Tenenbaum et al., 1999). Goal setting that is incorporated into an endurance athlete's training programme could lead to performance enhancement through its effect on quality or quantity of training. For example, endurance athletes who wish to improve their performance in an ultramarathon could set a combination of short-term and long-term goals to gradually increase their weekly running distance (Knechtle, Wirth, Knechtle, & Rosemann, 2010). Further, endurance athletes could work towards training process goals, such as adjusting running form or improving bike-handling techniques (e.g., cornering), that might be expected to deliver performance improvements. No studies conducted to date, however, have examined the effects of goal setting on the quality or quantity of endurance athletes' training and consequent long-term improvements in their performance. Future research could therefore examine the efficacy of goal-setting interventions as a training aid for endurance sports.

Finally, there is substantial evidence that psychological interventions could be used to enhance the competitive performances of endurance athletes. However, psychological interventions that enhance endurance performance could also be used to promote endurance exercise as a form of vigorous physical activity. Thousands of people participate in mass-participation endurance events (MPEEs), such as popular marathons and triathlons, for reasons other than competition, such as to raise money for charity, to engage in more physical activity, as a personal challenge, or to accompany a friend (Aoife Lane, Murphy, & Bauman, 2008). Mass-participation endurance events can have a beneficial effect on physical activity, because people who have registered for these events increase their physical activity to prepare for them (Bauman et al., 2012; Bowles, Rissel, & Bauman, 2006). Unfortunately, the physical activity of many entrants drops after the event to below recommended guidelines (Adams & White, 2009; Aoife Lane, Murphy, Bauman, & Chey, 2012; Aoife Lane et al., 2008). For example, the physical activity levels of approximately 2,000 more entrants was categorised as low 20 weeks after the 2008 Great North Run, compared to 20 weeks before (Adams & White, 2009). Interventions that facilitate continued participation in MPEEs, and associated training, could therefore help thousands of people to continue to achieve recommended minimum levels of physical activity. Psychological interventions that enhance endurance performance could potentially facilitate continued participation in MPEEs. For example, they could help entrants to persevere despite the strenuousness of the training, which could increase the probability of an entrant attending a MPEE and, through physiological adaptation, having the fitness required to complete it. Psychological interventions could also help entrants to optimise their performance in the event. By doing so, psychological interventions could increase the entrant's feelings of competence after the event, which would predict continued training and MPEE participation (Ryan et al., 1997). Future research might therefore examine the effects of psychological performance-enhancement interventions on physical activity levels before and after MPEEs.

Applied Implications

This thesis offers an evidence base for athletes, coaches, and practitioners interested in performance enhancement for endurance sports. In particular, endurance athletes could improve their performance times and competitive outcomes by learning psychological skills such as goal setting, imagery, or self-talk. Learning individual psychological skills or a combination of them has been shown to cause sustained improvements in running, swimming, and cycling endurance performance (Chapter 2). Practitioners teaching psychological skills should consider targeting the psychological demands that are experienced by endurance athletes and that can prevent optimal performance (Birrer & Morgan, 2010; Simons, 2012; Taylor, 1995). For example, based on the findings of Chapter 3, endurance athletes could use psychological skills to cope with exercise sensations, such as pain and exertion, and additional stressors encountered during an endurance event, such as being overtaken, performing below expectations, or a bike puncture. Chapter 5 offers preliminary support for the efficacy of teaching ultramarathon runners to use motivational self-talk to cope with the demands of an ultramarathon. Although additional data are required to draw firmer conclusions, ultramarathon runners who identified self-talk statements for the beginning, middle, and later stages of the ultramarathon, to counter thoughts about withdrawing effort, and in response to stressors (e.g., getting lost) finished 25 minutes faster, on average, than a control group.

An endurance athlete's pre-event activities and experiences can influence how well they perform and whether they enjoy the event. Indeed, in Chapter 3 (qualitative study), recreational endurance athletes described unexpected disruptions to their pre-performance preparation, such as running late to the event or forgetting equipment, that led to them feeling agitated, annoyed, or distracted. Endurance athletes are encouraged to identify and manage controllable aspects of preparation. For example, they could create a packing checklist, research expected road and car-park congestion, and prepare a timetable to arrive at the event early. In addition, endurance athletes should avoid mentally-draining activities before they compete, because mental fatigue has been shown to increase perception of effort and detrimentally affect endurance performance (e.g., Marcora et al., 2009). For example, endurance athletes should avoid situations that require them to suppress their emotions or behaviour (Wagstaff, 2014), such as interviews with the media. Similarly, recreational endurance athletes may choose to use familiar public-transport routes to MPEEs, to avoid mentally-draining navigation through busy city areas with closed roads. Practitioners and coaches could also teach endurance athletes alternative emotion-regulation strategies to suppression that they can use before the endurance event. Different emotion-regulation strategies, such as re-appraisal, might be more effective at regulating the emotion (Gross, 2002; Webb, Miles, & Sheeran, 2012) and have more desirable effects on perception of effort (Wagstaff, 2014) and cognitive performance (Gross, 2002) during the endurance event.

Head-to-head competition (e.g., Corbett et al., 2012) and verbal encouragement (e.g., Moffatt et al., 1994) enhance endurance performance. One factor that could contribute towards the dominance of East-African athletes, particularly Kenyan and Ethiopian athletes, in endurance running events is their highly-competitive environment. From childhood and adolescence, East-African runners frequently train with other world-class athletes at training camps, and they compete with each other for life-changing opportunities to escape poverty and to earn money to help their families (Pitsiladis, Onywera, Geogiades, O’Connell, & Boit, 2004; Wilber & Pitsiladis, 2012). This highly-competitive environment could cause East-African runners to push harder in training and accumulate slight advantages, such as greater physiological adaptation or greater confidence in their ability to persevere despite exertion (i.e., self-efficacy), over athletes from other countries. Coaches and practitioners could use competition and verbal encouragement to enhance endurance performance in training and competition. Motivational climates that are perceived as emphasising task goals (e.g., improving performance time, exerting greater effort) are associated with more favourable outcomes than motivational climates that are perceived as emphasising ego goals (e.g., outperforming other members of a club) (Harwood, Keegan, Smith, & Raine, 2015). The introduction of competition into the training environment should therefore be carefully planned so that it encourages athletes to focus on perceptions of competence that are self-referenced, rather than normatively-referenced. For example, athletes could start training races at different moments based on their anticipated performance time, and the coach could emphasise performance time over finishing position. As an additional suggestion, endurance athletes who train alone may find it motivating to use a training watch or mobile-phone application that allows them to compete against the times of other people or that delivers verbal encouragement at customised moments. Furthermore, verbal encouragement could be delivered systematically during solo endurance events. For example, video screens in stadiums could encourage a crowd to cheer louder during selected moments of an attempt to break the one-hour cycling record.

Finally, performance enhancement is only one service goal in applied sport psychology, and the broader remit of the sport psychologist includes the personal development, health, and wellbeing of the athlete (Brady & Maynard, 2010). Further, practitioners are typically encouraged to adopt a holistic approach to service delivery that may or may not include PST, depending on the needs of the individual athlete (e.g., Andersen, 2009; Brady & Maynard, 2010; McCann, 2011). Indeed, Chapter 3 (qualitative study) drew attention to stressors experienced outside of sport, such as the time investment to endurance sports and associated lifestyle sacrifices, that were sources of negatively-toned emotions such as frustration and guilt. It is therefore important that practitioners working with endurance athletes adopt a holistic approach to service delivery and consider demands experienced inside and outside of sport that influence non-performance outcomes such as enjoyment, satisfaction, stress, and worry. Nevertheless, some athletes do seek sport psychology support for performance enhancement. Further, in elite-level sport, performance is often seen as the most important outcome (Brady & Maynard, 2010; McCann, 2011). This thesis offers an evidence base for informing psychological interventions when the service goal is performance enhancement.

Limitations and Considerations

This thesis used a systematic literature review, a qualitative study using focus groups, a psychophysiology experiment in laboratory settings, and an experiment in field settings to examine psychologically-informed methods of enhancing endurance performance. Despite this methodological diversity, limitations were identified across chapters. With consideration to external validity, participants in the studies included in the systematic review and participants recruited for Chapters 3 to 5 were volunteers, rather than a random selection of the endurance athletes who, through their geographical location, would have been accessible for the studies (Bracht & Glass, 1968). The participants included in these studies may not therefore be representative of endurance athletes as an overall population. For example, endurance athletes included in the studies may have less time commitments. They may also have different attitudes towards sport psychology. For example, they may be less influenced by stigmas associated with working with a sport psychologist, they may have greater confidence in sport psychology consultants, and they may be more open to working with a sport psychologist (S. B. Martin, Bochum, Lavallee, & Page, 2002). As a consequence, people who volunteer for studies may be more likely to comply with psychological interventions, which could lead to a larger effect size. In other words, the findings of the studies are likely to have been influenced by who was able and willing to participate. Nevertheless, people who are willing and able to participate in studies might be more representative of sport psychology consumers than a random selection of endurance athletes if common characteristics, such as time availability and attitudes towards sport psychology, determine whether endurance athletes volunteer for studies and pursue psychological assistance.

In addition, the participants recruited for Chapters 3 to 5 were involved in endurance sports recreationally, rather than professionally. Similarly, the studies included in the systematic review typically recruited recreational exercisers or sub-elite endurance athletes. The intervention effect sizes calculated might therefore not generalise to elite populations of endurance athletes. Similarly, prominent psychological demands for elite endurance athletes are likely to vary from those described during the focus groups with recreational endurance athletes. For example, the time investment of participating in an endurance sport was a prominent psychological demand for recreational endurance athletes because these athletes also had separate employment commitments.

A key assumption of this thesis is that it is appropriate to group endurance sports together. In other words, this thesis assumes that performance in cycling, running, swimming, and other whole-body and dynamic forms of exercise, of various intensities and durations, are sufficiently similar for psychological principles to apply across exercise modes, distances, and durations. This assumption permeates the thesis through decisions such as considering outcome measures that range from 100-metres breaststroke swimming (Sheard & Golby, 2006) to ultra-endurance distances for the systematic review, including athletes from a range of sports and distances in the focus groups (Chapter 3), and designing a self-efficacy questionnaire using qualitative data relating to different sports and distances (Chapter 5). An alternative approach would be to research specific sports, race types (e.g., time trial versus road race), and distances, and to provide specialised psychological guidance. This approach to research is unnecessarily inefficient, however, if psychological interventions enhance performance in different endurance sports through common mechanisms that are particularly relevant to endurance performance. Although additional theoretically-informed studies were encouraged in order to offer greater clarity over the intervention-performance mechanisms, research conducted to date suggests that at least some psychological interventions influence endurance performance through common mechanisms. Specifically, they affect endurance performance through their effects on perception of effort (e.g., Blanchfield, Hardy, de Morree, et al., 2014; Marcora et al., 2009; Wagstaff, 2014). These interventions would therefore to be expected to enhance endurance performance in different endurance sports that are performed over various distances.

Additional support for grouping endurance sports together was found through the qualitative study reported in Chapter 3. Chapter 3 demonstrated that endurance athletes experience similar psychological demands across endurance sports and distances. Some psychological demands, of course, will be more prominent in certain sports and distances. For example, triathletes performing over longer distances particularly referred to the uncertainty they experienced over their pacing. Some psychological demands will also manifest differently in each specific sport. For example, the types of exercise-induced sensations experienced by endurance athletes depend on the type of sport and the intensity of exercise. Injury-related pain is a prominent exercise sensation for athletes competing over longer distances (Chapter 5; Holt et al., 2014), and exercise-induced muscle pain is more intense for athletes who train and compete at high intensity (Kress & Statler, 2007). The findings reported in this thesis offer a useful "starting point" for informing psychological interventions for enhancing performance in particular endurance sports and distances. Researchers and practitioners are encouraged to adapt interventions to the particular sport, as well as the needs and preferences of the athletes who will use the intervention. For example, in Chapter 5, ultramarathon runners were encouraged to use motivational self-talk when they encountered stressors that were likely to occur during the specific ultramarathon, such as when they got lost or “hit the wall”.

While this thesis assumed that it is appropriate to group endurance sports together, a related assumption is that endurance sports are somehow different from other types of sports. In other words, this thesis assumed that the psychological determinants of endurance performance vary from the psychological determinants of sport performance more generally. There are reasons to question this assumption. First, athletes from a range of sports encounter the psychological demands reported by recreational endurance athletes in Chapter 3 (qualitative study). For example, athletes from a range of sports have reported time demands and lifestyle sacrifices (e.g., Scanlan et al., 1991), encountering pre-performance stressors (e.g., Mellalieu et al., 2009), and encountering adversity during competition (e.g., Dugdale et al., 2002). Indeed, certain psychological demands, such as pressure to perform, are experienced by nearly all athletes (McKay et al., 2008; Noblet & Gifford, 2002; Thelwell et al., 2007). Certainly, some psychological aspects of performance in endurance sports are similar to performance in other sports. Nevertheless, some psychological aspects of performance are more prominent in endurance sports compared to other types of sport. In particular, exercise-induced muscle pain and perceived effort are experienced in many different sports that involve prolonged exercise, such as soccer and rugby. Persistence despite continuous pain and perceived effort, and careful pacing to control the increase in these exercise sensations (Marcora, 2010a; Mauger, 2014), however, characterises performance in endurance sports. A second reason to question whether endurance sports are different from other types of sport is that psychological interventions such as goal setting, imagery, and self-talk that enhance endurance performance also enhance performance in other sports (Curran, 2008; Hatzigeorgiadis et al., 2011; Kyllo & Landers, 1995). These interventions might operate through common psychological mechanisms in endurance and non-endurance sports. Research conducted to date on the psychological determinants of endurance performance, however, suggests that many psychological interventions affect endurance performance by influencing perception of effort (Chapter 2). Although psychological interventions that influence perception of effort can affect performance in other types of sport, such as soccer (M. R. Smith et al., 2016), this mechanism is particularly relevant to endurance sports. In essence, the differences between endurance sports and other sports, rather than the similarities between them, justifies researching endurance sports as a distinct group of sports.

Conclusions

The main focus of this thesis was to determine psychologically-informed methods of enhancing endurance performance, particularly in endurance sport events. There were three main research aims. First, this thesis aimed to synthesise research conducted to date on the psychological determinants of endurance performance. This aim was achieved by conducting a systematic literature review (Chapter 2) on the psychological determinants of endurance performance. Second, this thesis aimed to inform the design of performance-enhancement psychological interventions for endurance sports. This aim was achieved by identifying psychological demands that are commonly experienced by endurance athletes and that can be targeted by psychological performance-enhancement interventions (Chapter 3). Novel interventions informed by the facial feedback hypothesis that target the expression of a frown, however, would be unlikely to enhance endurance performance (Chapter 4). Third, this thesis aimed to examine the effect of a PST intervention on performance in a real-life endurance event. This thesis offers support that motivational self-talk possibly produces a performance enhancement that might benefit ultramarathon runners (Chapter 5), but additional data will be collected at the same ultramarathon in 2016 to drawer firmer conclusions.

Overall, the findings of this thesis draw attention to psychological factors such as perceived effort, pain, and emotional responses to stressors that can influence performance in endurance events, and it demonstrates that psychological interventions affect endurance performance. Some interventions such as PST, head-to-head competition, and verbal encouragement enhance endurance performance, whereas other interventions such as mental fatigue undermine endurance performance. This thesis provides an evidence base for people interested in endurance performance enhancement. In particular, endurance athletes could learn to use goal setting, imagery, and self-talk to cope with the demands of training and endurance events and to improve their performance. These PST interventions consistently enhance endurance performance in non-competitive endurance tasks in laboratory and field settings, and this thesis offers some preliminary evidence that self-talk enhances performance in real-life endurance events. Additional research that builds on this evidence base will help endurance athletes, coaches, and practitioners to maximise what sport psychology offers them. Nevertheless, given the consistent effects of psychological interventions on endurance performance, people involved in endurance sports, such as athletes and coaches, are encouraged to systematically work on the psychological aspects of training, preparing for a competition, and competing. After beating the one-hour cycling record last summer, Sir Bradley Wiggins stated, “It's a mental game more than a physical one” (“Sir Bradley Wiggins hour record attempt: as it happened,” 2015). Strategies for winning the mental game were scrutinised within this thesis.

Chapter 7

References

Abbiss, C. R., Peiffer, J. J., Meeusen, R., & Skorski, S. (2015). Role of ratings of perceived exertion during self-paced exercise: What are we actually measuring? *Sports Medicine*, *45*, 1235–1243. doi:10.1007/s40279-015-0344-5

Acevedo, E. O., Dzewaltowski, D. A., Gill, D. L., & Noble, J. M. (1992). Cognitive orientations of ultramarathoners. *The Sport Psychologist*, *6*, 242–252. Retrieved from http://journals.humankinetics.com/tsp

Achtziger, A., Gollwitzer, P. M., & Sheeran, P. (2008). Implementation intentions and shielding goal striving from unwanted thoughts and feelings. *Personality and Social Psychology Bulletin*, *34*, 381–393. doi:10.1177/0146167207311201

Adams, J., & White, M. (2009). The 2008 Great North Run as public health intervention: participant characteristics and changes in physical activity and body mass index from 20 weeks before to 20 weeks after the event. *Journal of Epidemiology & Community Health*, *63*(Suppl 2), A11. doi:10.1136/jech.2009.096701k

Albertus, Y., Tucker, R., St Clair Gibson, A., Lambert, E. V, Hampson, D. B., & Noakes, T. D. (2005). Effect of distance feedback on pacing strategy and perceived exertion during cycling. *Medicine & Science in Sports & Exercise*, *37*, 461–468. doi:10.1249/01.MSS.0000155700.72702.76

Amann, M., & Dempsey, J. A. (2009). When fatiguing cycling muscles complain, the brain insightfully responds! *Physiology News*, 13–14.

Amann, M., Hopkins, W. G., & Marcora, S. M. (2008). Similar sensitivity of time to exhaustion and time-trial time to changes in endurance. *Medicine & Science in Sports & Exercise*, *40*, 574–578. doi:10.1249/MSS.0b013e31815e728f

Amann, M., Proctor, L. T., Sebranek, J. J., Pegelow, D. F., & Dempsey, J. a. (2009). Opioid-mediated muscle afferents inhibit central motor drive and limit peripheral muscle fatigue development in humans. *The Journal of Physiology*, *587*, 271–283. doi:10.1113/jphysiol.2008.163303

Amann, M., & Secher, N. H. (2010). Rebuttal from Amann and Secher. *Journal of Applied Physiology*, *108*, 456–457. doi:10.1152/japplphysiol.00976.2009b

Andersen, M. (2009, June). Performance enhancement as a bad start and a dead end: A parenthetical comment on Mellalieu and Lane. *The Sport and Exercise Scientist*, 12–14. Retrieved from http://www.bases.org.uk/the-sport-and-exercise-scientist

Andreacci, J. L., Lemura, L. M., Cohen, S. L., Urbansky, E. A., Chelland, S. A., & von Duvillard, S. P. (2002). The effects of frequency of encouragement on performance during maximal exercise testing. *Journal of Sports Sciences*, *20*, 345–352. doi:10.1080/026404102753576125

Andreacci, J. L., Robertson, R. J., Goss, F. L., Randall, C. R., Tessmer, K. A., Nagle, E. F., & Gallagher, K. A. (2004). Frequency of verbal encouragement effects sub-maximal exertional perceptions during exercise testing with young adult women. *International Journal of Sport Psychology*, *35*, 267–283.

Anshel, M. H. (1995). Examining social loafing among elite female rowers as a function of task duration and mood. *Journal of Sport Behavior*, *18*, 39–49.

Appleby, K. M., & Dieffenbach, K. (2016). “Older and faster”: Exploring elite masters cyclists’ involvement in competitive sport. *The Sport Psychologist*, *30*, 13–23. doi:10.1123/tsp.2014-0110

Arnold, R., & Fletcher, D. (2012). A research synthesis and taxonomic classification of the organizational stressors encountered by sport performers. *Journal of Sport & Exercise Psychology*, *34*, 397–429. Retrieved from http://journals.humankinetics.com/jsep

Association, A. P. (2009). *Publication Manual of the American Psychological Association* (6th ed.). Washington, D.C.: American Psychological Association.

Astokorki, A. H. Y., & Mauger, A. R. (2016). Tolerance of exercise-induced pain at a fixed rating of perceived exertion predicts time trial cycling performance. *Scandinavian Journal of Medicine & Science in Sports*. doi:10.1111/sms.12659

Atkinson, G., Wilson, D., & Eubank, M. (2004). Effects of music on work-rate distribution during a cycling time trial. *International Journal of Sports Medicine*, *25*, 611–615. doi:10.1055/s-2004-815715

Baghurst, T., Thierry, G., & Holder, T. (2004). Evidence for a relationship between attentional styles and effective cognitive strategies during performance. *Athletic Insight*, *6*(1), 36–51.

Balagué, N., Hristovski, R., Garcia, S., Aragonés, D., Razon, S., & Tenenbaum, G. (2015). Intentional thought dynamics during exercise performed until volitional exhaustion. *Journal of Sports Sciences*, *33*, 48–57. doi:10.1080/02640414.2014.921833

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, *37*, 122–147. doi:10.1037//0003-066X.37.2.122

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares & T. Urdan (Eds.), *Self-efficacy beliefs of adolescents* (pp. 307–337). Greenwich, CT: Information Age.

Bandura, A., & Cervone, D. (1983). Self-evaluative and self-efficacy mechanisms governing the motivational effects of goal systems. *Journal of Personality and Social Psychology*, *45*, 1017–1028. doi:10.1037/0022-3514.45.5.1017

Bar-Eli, M., & Blumenstein, B. (2004a). Performance enhancement in swimming: the effect of mental training with biofeedback. *Journal of Science and Medicine in Sport*, *7*, 454–464. doi:10.1016/S1440-2440(04)80264-0

Bar-Eli, M., & Blumenstein, B. (2004b). The effect of extra-curricular mental training with biofeedback on short running performance of adolescent physical education pupils. *European Physical Education Review*, *10*(2), 123–134. doi:10.1177/1356336X04044055

Bar-Eli, M., Dreshman, R., Blumenstein, B., & Weinstein, Y. (2002). The effect of mental training with biofeedback on the performance of young swimmers. *Applied Psychology: An International Review, 51*, 567–581. doi:10.1111/1464-0597.00108

Bar-Eli, M., Tenenbaum, G., Pie, J. S., Btesh, Y., & Almog, A. (1997). Effect of goal difficulty, goal specificity and duration of practice time intervals on muscular endurance performance. *Journal of Sports Sciences, 15*, 125–135. doi:10.1080/026404197367407

Barker, J., McCarthy, P., Jones, M., & Moran, A. (2011). *Single-case research methods in sport and exercise psychology*. Abingdon, England: Routledge.

Barling, J., & Bresgi, I. (1982). Cognitive factors in athletic (swimming) performance: A re-examination. *The Journal of General Psychology, 107,* 227–231. doi:10.1080/00221309.1982.9709930

Barwood, M. J., Corbett, J., Wagstaff, C. R. D., McVeigh, D., & Thelwell, R. C. (2015). Improvement of 10-km time-trial cycling with motivational self-talk compared with neutral self-talk. *International Journal of Sports Physiology and Performance, 10*, 166–171. doi:10.1123/ijspp.2014-0059

Barwood, M. J., Thelwell, R. C., & Tipton, M. J. (2008). Psychological skills training improves exercise performance in the heat. *Medicine & Science in Sports & Exercise*, *40*, 387–396. doi:10.1249/mss.0b013e31815adf31

Barwood, M. J., Weston, N. J. V, Thelwell, R., & Page, J. (2009). A motivational music and video intervention improves high-intensity exercise performance. *Journal of Sports Science and Medicine*, *8*(3), 435–442. Retrieved from http://www.jssm.org/

Bassett, D. R., & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine & Science in Sports & Exercise*, *32*, 70–84. doi:10.1097/00005768-200001000-00012

Bath, D., Turner, L. A., Bosch, A. N., Tucker, R., Lambert, E. V, Thompson, K. G., & St Clair Gibson, A. (2012). The effect of a second runner on pacing strategy and RPE during a running time trial. *International Journal of Sports Physiology and Performance*, *7*, 26–32. Retrieved from http://journals.humankinetics.com/ijspp

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*, 50–57. Retrieved from http://journals.humankinetics.com/ijspp

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F., & Martin, B. W. (2012). Correlates of physical activity: why are some people physically active and others not? *Lancet*, *380*(9838), 258–271. doi:10.1016/S0140-6736(12)60735-1

Bauman, A. E., Sallis, J. F., Dzewaltowski, D. A., & Owen, N. (2002). Toward a better understanding of the influences on physical activity: The role of determinants, correlates, causal variables, mediators, moderators, and confounders. *American Journal of Preventive Medicine*, *23*(2S), 5–14. doi:10.1016/S0749-3797(02)00469-5

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology*, *74*, 1252–1265. doi:10.1037/0022-3514.74.5.1252

Beauchamp, M. K., Harvey, R. H., & Beauchamp, P. H. (2012). An integrated biofeedback and psychological skills training program for Canada's Olympic short-track speedskating team. *Journal of Clinical Sport Psychology*, *6*, 67–84. Retrieved from http://journals.humankinetics.com/jcsp

Beedie, C. J., & Foad, A. J. (2009). The placebo effect in sports performance: A brief review. *Sports Medicine*, *39*, 313–329. doi:10.2165/00007256-200939040-00004

Beeson, P. M., & Robey, R. R. (2006). Evaluating single-subject treatment research: Lessons learned from the aphasia literature. *Neuropsychology Review*, *16*, 161–169. doi:10.1007/s11065-006-9013-7

Bérdi, M., Köteles, F., Szabó, A., & Bárdos, G. (2011). Placebo effects in sport and exercise: A meta-analysis. *European Journal of Mental Health*, *6*, 196–212. doi:10.5708/EJMH.6.2011.2.5

Biel, A. (2005). *Trail guide to the body* (3rd ed.). Boulder, CO: Books of Discovery.

Birrer, D., & Morgan, G. (2010). Psychological skills training as a way to enhance an athlete's performance in high-intensity sports. *Scandinavian Journal of Medicine & Science in Sports*, *20 (Suppl. 2)*, 78–87. doi:10.1111/j.1600-0838.2010.01188.x

Bishop, D. T., Karageorghis, C. I., & Loizou, G. (2007). A grounded theory of young tennis players' use of music to manipulate emotional state. *Journal of Sport & Exercise Psychology*, *29*, 584–607. doi:http://journals.humankinetics.com/jsep

Blanchfield, A., Hardy, J., & Marcora, S. (2014). Non-conscious visual cues related to affect and action alter perception of effort and endurance performance. *Frontiers in Human Neuroscience*, *8*, 967. doi:10.3389/fnhum.2014.00967

Blanchfield, A. W., Hardy, J., de Morree, H. M., Staiano, W., & Marcora, S. M. (2014). Talking yourself out of exhaustion: The effects of self-talk on endurance performance. *Medicine & Science in Sports & Exercise*, *46*, 998–1007. doi:10.1249/MSS.0000000000000184

Boot, W. R., Simons, D. J., Stothart, C., & Stutts, C. (2013). The pervasive problem with placebos in psychology: Why active control groups are not sufficient to rule out placebo effects. *Perspectives on Psychological Science*, *8*, 445–454. doi:10.1177/1745691613491271

Borg, G. A. (1998). *Borg's perceived exertion and pain scales*. Champaign, IL: Human Kinetics.

Borg, W. (1984). Dealing with threats to internal validity that randomization does not rule out. *Educational Researcher*, *13*(10), 11–14. doi:10.3102/0013189X013010011

Boutcher, S. H., Fleischer-Curtian, L. A., & Gines, S. D. (1988). The effects of self-presentation on perceived exertion. *Journal of Sport & Exercise Psychology*, *10*, 270–280. Retrieved from http://journals.humankinetics.com/jsep

Bowles, H. R., Rissel, C., & Bauman, A. (2006). Mass community cycling events: Who participates and is their behaviour influenced by participation? *International Journal of Behavioral Nutrition and Physical Activity*, *3*, 39. doi:10.1186/1479-5868-3-39

Bracht, G. H., & Glass, G. V. (1968). The external validity of experiments. *American Educational Research Journal*, *5*, 437–474. doi:10.3102/00028312005004437

Brady, A., & Maynard, I. (2010). Debate: At an elite level the role of a sport psychologist is entirely about performance enhancement. *Sport & Exercise Psychology Review*, *6*(1), 59–66.

Brasher hails an astonishing day. (2015). Retrieved from https://www.virginmoneylondonmarathon.com/en-gb/news-media/latest-news/item/brasher-hails-an-astonishing-day/

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*, 77–101. doi:10.1191/1478088706qp063oa

Brehm, J. W., & Self, E. A. (1989). The intensity of motivation. *Annual Review of Psychology*, *40*, 109–131. doi:10.1146/annurev.ps.40.020189.000545

Breslin, G., Murphy, M. H., Kremer, J., McClean, C., & Davison, G. (2014). Providing sport psychology support to an athlete in a unique, ultra-endurance event. *Journal of Sport Psychology in Action*, *5*, 59–72. doi:10.1080/21520704.2014.892911

Brewer, B. W., & Buman, M. P. (2006). Attentional focus and endurance performance: Review and theoretical integration. *Kinesiologia Slovenica*, *12*, 82–97. Retrieved from http://www.kinsi.si/

Brick, N., MacIntyre, T., & Campbell, M. (2014). Attentional focus in endurance activity: New paradigms and future directions. *International Review of Sport and Exercise Psychology*, *7*, 106–134. doi:10.1080/1750984X.2014.885554

Brick, N., MacIntyre, T., & Campbell, M. (2015). Metacognitive processes in the self-regulation of performance in elite endurance runners. *Psychology of Sport and Exercise*, *19*, 1–9. doi:10.1016/j.psychsport.2015.02.003

Bubb, W. J., Myers, B. C., Claytor, R. P., Varnum, D. L., Watts, L., & Franks, B. D. (1985). Experimenter effects in exercise tolerance testing: The race and gender of the tester and the tester/subject relationship. *Research Quarterly for Exercise and Sport*, *56*, 370–377. doi:10.1080/02701367.1985.10605343

Bueno, J., Weinberg, R. S., Fernández-Castro, J., & Capdevila, L. (2008). Emotional and motivational mechanisms mediating the influence of goal setting on endurance athletes' performance. *Psychology of Sport and Exercise*, *9*(6), 786–799. doi:10.1016/j.psychsport.2007.11.003

Bull, S. J. (1989). The role of the sport psychology consultant: A case study of ultra-distance running. *The Sport Psychologist*, *3*, 254–264. Retrieved from http://journals.humankinetics.com/tsp

Buman, M. P., Omli, J. W., Giacobbi, P. R., & Brewer, B. W. (2008). Experiences and coping responses of "hitting the wall" for recreational marathon runners. *Journal of Applied Sport Psychology*, *20*, 282–300. doi:10.1080/10413200802078267

Burhans, R. S., Richman, C. L., & Bergey, D. B. (1988). Mental imagery training: Effects on running speed performance. *International Journal of Sport Psychology*, *19*, 26–37.

Burnley, M., & Jones, A. M. (2007). Oxygen uptake kinetics as a determinant of sports performance. *European Journal of Sport Science*, *7*, 63–79. doi:10.1080/17461390701456148

Burton, D. (1989). Winning isn't everything: Examining the impact of performance goals on collegiate swimmers' cognitions and performance. *The Sport Psychologist*, *3*, 105–132. Retrieved from http://journals.humankinetics.com/tsp

Cacioppo, J. T., Petty, R. E., & Morris, K. J. (1985). Semantic, evaluative, and self-referent processing: Memory, cognitive effort, and somatovisceral activity. *Psychophysiology*, *22*, 371–384. doi:10.1111/j.1469-8986.1985.tb01618.x

Caird, S. J., McKenzie, A. D., & Sleivert, G. G. (1999). Biofeedback and relaxation techniques improve running economy in sub-elite long distance runners. *Medicine & Science in Sports & Exercise*, *31*, 717–722. doi:10.1097/00005768-199905000-00015

Callow, N., Roberts, R., & Fawkes, J. Z. (2006). Effects of dynamic and static imagery on vividness of imagery, skiing performance, and confidence. *Journal of Imagery Research in Sport and Physical Activity*, *1*, 2. doi:10.2202/1932-0191.1001

Callow, N., Roberts, R., Hardy, L., Jiang, D., & Edwards, M. G. (2013). Performance improvements from imagery: evidence that internal visual imagery is superior to external visual imagery for slalom performance. *Frontiers in Human Neuroscience*, *7*, 697. doi:10.3389/fnhum.2013.00697

Campbell, D. T., & Stanley, J. C. (1966). *Experimental and quasi-experimental designs for research*. Boston, MA: Houghton Mifflin.

Capelli, C., Schena, F., Zamparo, P., Dal Monte, A., Faina, M., & di Prampero, P. E. (1998). Energetics of best performances in track cycling. *Medicine & Science in Sports & Exercise*, *30*, 614–624. doi:10.1097/00005768-199804000-00021

Carnes, A. J., Barkley, J. E., Williamson, M., & Sanders, G. (2013). The presence of a familiar peer does not affect intensity or enjoyment during treadmill exercise in male distance runners or non-runners. *Journal of Athletic Enhancement*, *2*(4). doi:10.4172/2324-9080.1000119

Cejka, N., Rüst, C. A., Lepers, R., Onywera, V., Rosemann, T., & Knechtle, B. (2014). Participation and performance trends in 100-km ultra-marathons worldwide. *Journal of Sports Sciences*, *32*, 354–366. doi:10.1080/02640414.2013.825729

Chitwood, L. F., Moffatt, R. J., Burke, K., Luchino, P., & Jordan, J. C. (1997). Encouragement during maximal exercise testing of Type A and Type B scorers. *Perceptual and Motor Skills*, *84*, 507–512. doi:10.2466/pms.1997.84.2.507

Clark, V. R., Hopkins, W. G., Hawley, J. A., & Burke, L. M. (2000). Placebo effect of carbohydrate feedings during a 40-km cycling time trial. *Medicine & Science in Sports & Exercise*, *32*, 1642–1647. doi:10.1097/00005768-200009000-00019

Clingman, J. M., & Hilliard, D. V. (1990). Race walkers quicken their pace by tuning in, not stepping out. *The Sport Psychologist*, *4*, 25–32. Retrieved from http://journals.humankinetics.com/tsp

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Connolly, C. T., & Janelle, C. M. (2003). Attentional strategies in rowing: Performance, perceived exertion, and gender considerations. *Journal of Applied Sport Psychology*, *15*, 195–212. doi:10.1080/10413200305387

Conroy, D. E., Elliot, A. J., & Hofer, S. M. (2003). A 2 X 2 Achievement Goals Questionnaire for sport: Evidence for factorial invariance, temporal stability, and external validity. *Journal of Sport & Exercise Psychology*, *25*, 456–476. Retrieved from http://journals.humankinetics.com/jsep

Cook, D. B., O'Connor, P. J., Eubanks, S. A., Smith, J. C., & Lee, M. (1997). Naturally occurring muscle pain during exercise: assessment and experimental evidence. *Medicine &*

Science in Sports & Exercise, *29*, 999–1012. Retrieved from http://journals.lww.com/acsm-msse

Copeland, B. L., & Franks, B. D. (1991). Effects of types and intensities of background music on treadmill endurance. *The Journal of Sports Medicine and Physical Fitness*, *31*, 100–103.

Corbett, J., Barwood, M. J., Ouzounoglou, A., Thelwell, R., & Dicks, M. (2012). Influence of competition on performance and pacing during cycling exercise. *Medicine & Science in Sports & Exercise*, *44*, 509–515. doi:10.1249/MSS.0b013e31823378b1

Couture, R. T., Jerome, W., & Tihanyi, J. (1999). Can associative and dissociative strategies affect the swimming performance of recreational swimmers? *The Sport Psychologist*, *13*, 334–343. Retrieved from http://journals.humankinetics.com/tsp

Crust, L., & Clough, P. J. (2005). Relationship between mental toughness and physical endurance. *Perceptual and Motor Skills*, *100*, 192–194. doi:10.2466/pms.100.1.192-194

Crust, L., Nesti, M., & Bond, K. (2010). Mental toughness and coping in an ultra-endurance event. *Athletic Insight*, *12*(1), 35–54. Retrieved from http://www.athleticinsight.com/

Curran, M. L. (2008). *Imagery – "The icing on the cake". A meta-analytic evaluation of the effect of imagery on sport and exercise* (Unpublished master's thesis). University of Southern Queensland, Toowoomba, Queensland, Australia.

Currell, K., & Jeukendrup, A. E. (2008). Validity, reliability and sensitivity of measures of sporting performance. *Sports Medicine*, *38*, 297–316. doi:10.2165/00007256-200838040-00003

Darwin, C. (1913). *The expression of the emotions in man and animals*. New York, NY: D. Appleton and Company.

Davis, J. I., Senghas, A., Brandt, F., & Ochsner, K. N. (2010). The effects of BOTOX injections on emotional experience. *Emotion*, *10*, 433–440. doi:10.1037/a0018690

Davis, J. I., Senghas, A., & Ochsner, K. N. (2009). How does facial feedback modulate emotional experience? *Journal of Research in Personality*, *43*, 822–829. doi:10.1016/j.jrp.2009.06.005

De Koning, J. J., Foster, C., Bakkum, A., Kloppenburg, S., Thiel, C., Joseph, T., … Porcari, J. P. (2011). Regulation of pacing strategy during athletic competition. *PLoS ONE*, *6*(1), e15863. doi:10.1371/journal.pone.0015863

De Morree, H. M., & Marcora, S. M. (2010). The face of effort: Frowning muscle activity reflects effort during a physical task. *Biological Psychology*, *85*, 377–382. doi:10.1016/j.biopsycho.2010.08.009

De Morree, H. M., & Marcora, S. M. (2012). Frowning muscle activity and perception of effort during constant-workload cycling. *European Journal of Applied Physiology*, *112*, 1967–1972. doi:10.1007/s00421-011-2138-2

De Morree, H. M., & Marcora, S. M. (2013). Effects of isolated locomotor muscle fatigue on pacing and time trial performance. *European Journal of Applied Physiology*, *113*, 2371–2380. doi:10.1007/s00421-013-2673-0

De Petrillo, L. A., Kaufman, K. A., Glass, C. R., & Arnkoff, D. B. (2009). Mindfulness for long-distance runners: An open trial using Mindful Sport Performance Enhancement (MSPE). *Journal of Clinical Sport Psychology*, *3*, 357–376. Retrieved from http://journals.humankinetics.com/jcsp

Desharnais, R., Bouillon, J., & Godin, G. (1986). Self-efficacy and outcome expectations as determinants of exercise adherence. *Psychological Reports*, *59*, 1155–1159. doi:10.2466/pr0.1986.59.3.1155

Di Prampero, P. E. (2003). Factors limiting maximal performance in humans. *European Journal of Applied Physiology*, *90*, 420–429. doi:10.1007/s00421-003-0926-z

Díaz-Ocejo, J., Kuitunnen, S., & Mora-Mérida, J. A. (2013). An intervention to enhance the performance of a 3000 metre steeplechase athlete with the use of segmentation and self-talk. *Revista de PsicologÃa Del Deporte*, *22*, 87–92.

Donohue, B., Barnhart, R., Covassin, T., Carpin, K., & Korb, E. (2001). The development and initial evaluation of two promising mental preparatory methods in a sample of female cross country runners. *Journal of Sport Behavior*, *24*, 19–30.

Donohue, B., Miller, A., Beisecker, M., Houser, D., Valdez, R., Tiller, S., & Taymar, T. (2006). Effects of brief yoga exercises and motivational preparatory interventions in distance runners: Results of a controlled trial. *British Journal of Sports Medicine*, *40*, 60–63. doi:10.1136/bjsm.2005.020024

Dosil, J. (2006). The psychology of athletics. In J. Dosil (Ed.), *The sport psychologist's handbook: A guide for sport-specific performance enhancement* (pp. 265–284). Chichester, England: John Wiley & Sons.

Dugdale, J. R., Eklund, R. C., & Gordon, S. (2002). Expected and unexpected stressors in major international competition: Appraisal, coping, and performance. *The Sport Psychologist*, *16*, 20–33. Retrieved from http://journals.humankinetics.com/tsp

Ebben, W. P., Leigh, D. H., & Geiser, C. F. (2008). The effect of remote voluntary contractions on knee extensor torque. *Medicine & Science in Sports & Exercise*, *40*, 1805–1809. doi:10.1249/MSS.0b013e31817dc4ad

Ekkekakis, P., Parfitt, G., & Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities: Decennial update and progress towards a tripartite rationale for exercise intensity prescription. *Sports Medicine*, *41*, 641–671. doi:10.2165/11590680-000000000-00000

Ekman, P. (2004). *Emotions revealed: Understanding faces and feelings*. London, England: Phoenix.

Elliot, A. J., & Murayama, K. (2008). On the measurement of achievement goals: Critique, illustration, and application. *Journal of Educational Psychology*, *100*, 613–628. doi:10.1037/0022-0663.100.3.613

Enoka, R. M., & Stuart, D. G. (1992). Neurobiology of muscle fatigue. *Journal of Applied Physiology*, *72*, 1631–1648. Retrieved from http://jap.physiology.org/

Esfarjani, F., & Laursen, P. B. (2007). Manipulating high-intensity interval training: effects on VO2max, the lactate threshold and 3000 m running performance in moderately trained males. *Journal of Science and Medicine in Sport*, *10*, 27–35. doi:10.1016/j.jsams.2006.05.014

Everett, J. J., Smith, R. E., & Williams, K. D. (1992). Effects of team cohesion and identifiability on social loafing in relay swimming performance. *International Journal of Sport Psychology*, *23*, 311–324.

Farrell, P. A., Wilmore, J. H., Coyle, E. F., Billing, J. E., & Costill, D. L. (1979). Plasma lactate accumulation and distance running performance. *Medicine & Science in Sports & Exercise*, *11*, 338–344. doi:10.1249/00005768-199310000-00002

Faul, F., Erdfelder, E., Lang, A., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavioral Research Methods*, *39*, 175–191. doi:10.3758/BF03193146

Faulkner, J., Arnold, T., & Eston, R. (2011). Effect of accurate and inaccurate distance feedback on performance markers and pacing strategies during running. *Scandinavian Journal of Medicine & Science in Sports*, *21*, e176–183. doi:10.1111/j.1600-0838.2010.01233.x

Feltz, D. L., & Riessinger, C. A. (1990). Effects of in vivo emotive imagery and performance feedback on self-effficacy and muscular endurance. *Journal of Sport and Exercise Psychology*, *12*, 132–143. Retrieved from http://journals.humankinetics.com/jsep

Fillingim, R. B., & Fine, M. A. (1986). The effects of internal versus external information processing on symptom perception in an exercise setting. *Health Psychology*, *5*, 115–123.

Fillingim, R. B., Roth, D. L., & Haley, W. E. (1989). The effects of distraction on the perception of exercise-induced symptoms. *Journal of Psychosomatic Research*, *33*, 241–248.

Fletcher, D., Hanton, S., & Mellalieu, S. D. (2006). An organizational stress review: Conceptual and theoretical issues in competitive sport. In S. Hanton & S. D. Mellalieu (Eds.), *Literature reviews in sport psychology* (pp. 321–373). New York, NY: Nova Science.

Fletcher, D., Hanton, S., Mellalieu, S. D., & Neil, R. (2012). A conceptual framework of organizational stressors in sport performers. *Scandinavian Journal of Medicine & Science in Sports*, *22*, 545–557. doi:10.1111/j.1600-0838.2010.01242.x

Foster, C., Green, M. A., Snyder, A. C., & Thompson, N. N. (1993). Physiological responses during simulated competition. *Medicine & Science in Sports & Exercise*, *25*, 877–882. doi:10.1249/00005768-199307000-00018

Franks, B. D., & Myers, B. C. (1984). Effects of talking on exercise tolerance. *Research Quarterly for Exercise and Sport*, *55*, 237–241. doi:10.1080/02701367.1984.10609358

Freund, W., Weber, F., Billich, C., Birklein, F., Breimhorst, M., & Schuetz, U. H. (2013). Ultra-marathon runners are different: Investigations into pain tolerance and personality traits of participants of the TransEurope footrace 2009. *Pain Practice*, *13*, 524–532. doi:10.1111/papr.12039

Friesen, A., & Orlick, T. (2010). A qualitative analysis of holistic sport psychology consultants' professional philosophies. *The Sport Psychologist*, *24*, 227–244. Retrieved from http://journals.humankinetics.com/tsp

Gammage, K. L., Hardy, J., & Hall, C. R. (2001). A description of self-talk in exercise. *Psychology of Sport and Exercise*, *2*, 233–247. doi:10.1016/S1469-0292(01)00011-5

Gardner, M. J., & Altman, D. G. (1986). Confidence intervals rather than P values: estimation rather than hypothesis testing. *British Medical Journal*, *292*, 746–750. doi:10.1136/bmj.292.6522.746

Gastin, P. B. (2001). Energy system interaction and relative contribution during maximal exercise. *Sports Medicine*, *31*, 725–741. doi:10.2165/00007256-200131100-00003

Gerosa, D., Rüst, C. A., Rosemann, T., & Knechtle, B. (2014). Participation and performance trends in 161km ultra-marathons in terms of nationality – a retrospective data analysis of worldwide participation from 1998-2011. *Journal of Human Sport and Exercise, 9,* 592–615. doi:10.14198/jhse.2014.92.01

Giacobbi, P. R., Poczwardowski, A., & Hager, P. F. (2005). A pragmatic research philosophy for applied sport psychology. *The Sport Psychologist*, *19*, 18–31. Retrieved from http://journals.humankinetics.com/TSP

Goodmurphy, C. W., & Ovalle, W. K. (1999). Morphological study of two human facial muscles: Orbicularis oculi and corrugator supercilii. *Clinical Anatomy*, *12*, 1–11. doi:10.1002/(SICI)1098-2353(1999)12:1<1::AID-CA1>3.0.CO;2-J

Goudas, M., Theodorakis, Y., & Laparidis, K. (2007). The effect of external versus internal types of feedback and goal setting on endurance performance. *Athletic Insight*, *9*(3), 57–66.

Gould, D., Jackson, S., & Finch, L. (1993). Sources of stress in national champion figure skaters. *Journal of Sport & Exercise Psychology*, *15*, 134–159. Retrieved from http://journals.humankinetics.com/jsep

Gould, D., Tuffey, S., Hardy, L., & Lochbaum, M. (1993). Multidimensional state anxiety and middle distance running performance: An exploratory examination of Hanin's (1980) zones of optimal functioning hypothesis. *Journal of Applied Sport Psychology*, *5*, 85–94. doi:10.1080/10413209308411307

Gravel, R., Lemieux, G., & Ladouceur, R. (1980). Effectiveness of a cognitive behavioral treatment package for cross-country ski racers. *Cognitive Therapy and Research*, *4*, 83–89. doi:10.1007/BF01173357

Great North Run: Farah wins as thousands take on half marathon. (2015). Retrieved from http://www.bbc.co.uk/news/uk-england-tyne-34200323

Greenlees, I. A., Graydon, J. K., & Maynard, I. W. (1999). The impact of collective efficacy beliefs on effort and persistence in a group task. *Journal of Sports Sciences*, *17,* 151–158. doi:10.1080/026404199366253

Greenlees, I., Thelwell, R., & Holder, T. (2006). Examining the efficacy of the concentration grid exercise as a concentration enhancement exercise. *Psychology of Sport and Exercise*, *7,* 29–39. doi:10.1016/j.psychsport.2005.02.001

Gregg, M. J., Hrycaiko, D., Mactavish, J. B., & Martin, G. L. (2004). A mental skills package for Special Olympics Athletes: A preliminary study. *Adapted Physical Activity Quarterly*, *21*, 4–18. Retrieved from http://journals.humankinetics.com/apaq

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, *2,* 271–299. doi:10.1037/1089-2680.2.3.271

Gross, J. J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology*, *39*, 281–291. doi:10.1017.S0048577201393198

Hall, H. K., & Byrne, A. T. J. (1988). Goal setting in sport: Clarifying recent anomalies. *Journal of Sport & Exercise Psychology*, *10*, 184–198.

Halson, S. L., & Martin, D. T. (2013). Lying to win-Placebos and sport science. *International Journal of Sports Physiology and Performance*, *8*, 597–599. Retrieved from http://journals.humankinetics.com/ijspp

Hambleton, P. (1992). Clostridium botulinum toxins: a general review of involvement in disease, structure, mode of action and preparation for clinical use. *Journal of Neurology*, *239*, 16–20. doi:10.1007/BF00839205

Hamilton, R. A., Scott, D., & MacDougall, M. P. (2007). Assessing the effectiveness of self-talk interventions on endurance performance. *Journal of Applied Sport Psychology*, *19*, 226–239. doi:10.1080/10413200701230613

Hammermeister, J., & Burton, D. (2001). Stress, appraisal, and coping revisited: Examining the antecedents of competitive state anxiety with endurance athletes. *The Sport Psychologist*, *15*, 66–90. Retrieved from http://journals.humankinetics.com/tsp

Hanley, B. (2014). Senior men's pacing profiles at the IAAF World Cross Country Championships. *Journal of Sports Sciences*, *32*, 1060–1065. doi:10.1080/02640414.2013.878807

Hanton, S., & Jones, G. (1999). The effects of a multimodal intervention program on performers: II. Training the butterflies to fly in formation. *The Sport Psychologist*, *13*, 22–41. Retrieved from http://journals.humankinetics.com/tsp

Hardy, C. J., Hall, E. G., & Prestholdt, P. H. (1986). The mediational role of social influence in the perception of exertion. *Journal of Sport & Exercise Psychology*, *8*, 88–104. Retrieved from http://journals.humankinetics.com/jsep

Hardy, C. J., & Rejeski, W. J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journal of Sport & Exercise Psychology*, *11*, 304–317. Retrieved from http://journals.humankinetics.com/jsep

Harris, D. V, & Harris, B. L. (1984). *The athlete's guide to sport psychology: Mental skills for physical people*. New York, NY: Leisure Press.

Hart, S. G. (2006). Nasa-Task Load Index (NASA-TLX); 20 Years Later. *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*, *50*, 904–908. doi:10.1177/154193120605000909

Harwood, C. G., Keegan, R. J., Smith, J. M. J., & Raine, A. S. (2015). A systematic review of the intrapersonal correlates of motivational climate perceptions in sport and physical activity. *Psychology of Sport and Exercise*, *18*, 9–25. doi:10.1016/j.psychsport.2014.11.005

Hatzigeorgiadis, A., Galanis, E., Zourbanos, N., & Theodorakis, Y. (2014). Self-talk and competitive sport performance. *Journal of Applied Sport Psychology*, *26*, 82–95. doi:10.1080/10413200.2013.790095

Hatzigeorgiadis, A., Zourbanos, N., Galanis, E., & Theodorakis, Y. (2011). Self-talk and sports performance: A meta-analysis. *Perspectives on Psychological Science*, *6*, 348–356. doi:10.1177/1745691611413136

Havas, D. A., Glenberg, A. M., Gutowski, K. A., Lucarelli, M. J., & Davidson, R. J. (2010). Cosmetic use of Botulinum Toxin-A affects processing of emotional language. *Psychological Science*, *21*, 895–900. doi:10.1177/0956797610374742

Heckmann, M., Teichmann, B., Schroder, U., Sprengelmeyer, R., & Ceballos-Baumann, A. O. (2003). Pharmacologic denervation of frown muscles enhances baseline expression of happiness and decreases baseline expression of anger, sadness, and fear. *Journal of the American Academy of Dermatology*, *49*, 213–216. doi:10.1067/S0190-9622(03)00909-5

Higgs, S. L. (1972). The effect of competition upon the endurance performance of college women. *International Journal of Sport Psychology*, *3*, 128–140.

Hill, D. W. (1993). The critical power concept. *Sports Medicine*, *16*, 237–254. doi:10.2165/00007256-199316040-00003

Hodgins, H. S., Yacko, H. A., & Gottlieb, E. (2006). Autonomy and nondefensiveness. *Motivation and Emotion*, *30*, 283–293. doi:10.1007/s11031-006-9036-7

Hoffman, M. D., Ong, J. C., & Wang, G. (2010). Historical analysis of participation in 161 km ultramarathons in North America. *The International Journal of the History of Sport*, *27*, 1877–1891. doi:10.1080/09523367.2010.494385

Hojat, M., & Xu, G. (2004). A visitor's guide to effect sizes: Statistical significance versus practical (clinical) importance of research findings. *Advances in Health Sciences Education*, *9*, 241–249. doi:10.1023/B:AHSE.0000038173.00909.f6

Hollander, D. B., & Acevedo, E. O. (2000). Successful English Channel swimming: The peak experience. *The Sport Psychologist*, *14*, 1–16. Retrieved from http://journals.humankinetics.com/tsp

Holt, N. L., Lee, H., Kim, Y., & Klein, K. (2014). Exploring experiences of running an ultramarathon. *The Sport Psychologist*, *28*, 22–35. doi:10.1123/tsp.2013-0008

Hopkins, W. G. (2000). Quantitative research design. *Sportscience*, *4*(1). Retrieved from http://www.sportsci.org/

Hopkins, W. G., Schabort, E. J., & Hawley, J. A. (2001). Reliability of power in physical performance tests. *Sports Medicine*, *31*, 211–234. doi:10.2165/00007256-200131030-00005

Houston, M., Dolan, S., & Martin, S. (2011). The impact of physical, nutritional, and mental preparation on triathlon performance. *The Journal of Sports Medicine and Physical Fitness*, *51*, 583–594.

Huang, D.-H., & Chiou, W.-K. (2013). Validation of a facial pictorial rating of perceived exertion scale for evaluating physical tasks. *Journal of Industrial and Production Engineering*, *30*, 125–131. doi:10.1080/21681015.2013.788079

Huang, D.-H., Chou, S.-W., Chen, Y.-L., & Chiou, W.-K. (2014). Frowning and jaw clenching muscle activity reflects the perception of effort during incremental workload cycling. *Journal of Sports Science and Medicine*, *13*, 921–928. Retrieved from http://www.jssm.org/

Hulleman, M., De Koning, J. J., Hettinga, F. J., & Foster, C. (2007). The effect of extrinsic motivation on cycle time trial performance. *Medicine & Science in Sports & Exercise*, *39*, 709–715. doi:10.1249/mss.0b013e31802eff36

Hurdiel, R., Pezé, T., Daugherty, J., Girard, J., Poussel, M., Poletti, L., … Theunynck, D. (2014). Combined effects of sleep deprivation and strenuous exercise on cognitive performances during The North Face® Ultra Trail du Mont Blanc® (UTMB®). *Journal of Sports Sciences*, *33*, 670–674. doi:10.1080/02640414.2014.960883

Hutchinson, J. C., Sherman, T., Martinovic, N., & Tenenbaum, G. (2008). The effect of manipulated self-efficacy on perceived and sustained effort. *Journal of Applied Sport Psychology*, *20*, 457–472. doi:10.1080/10413200802351151

Hutchinson, J. C., & Tenenbaum, G. (2007). Attention focus during physical effort: The mediating role of task intensity. *Psychology of Sport and Exercise*, *8*, 233–245. doi:10.1016/j.psychsport.2006.03.006

Ingham, S. A., Whyte, G. P., Jones, K., & Nevill, A. M. (2002). Determinants of 2,000 m rowing ergometer performance in elite rowers. *European Journal of Applied Physiology*, *88*, 243–246. doi:10.1007/s00421-002-0699-9

Ivy, J. L., Kammer, L., Ding, Z., Wang, B., Bernard, J. R., Liao, Y. H., & Hwang, J. (2009). Improved cycling time-trial performance after ingestion of a caffeine energy drink. *International Journal of Sport Nutrition and Exercise Metabolism*, *19*, 61–78. Retrieved from http://journals.humankinetics.com/ijsnem

Jackson, J. A., Gass, G. C., & Camp, E. M. (1979). The relationship between posthypnotic suggestion and endurance in physically trained subjects. *The International Journal of Clinical and Experimental Hypnosis*, *27*, 278–293. doi:10.1080/00207147908407567

Jacobs, I., & Bell, D. G. (2004). Effects of acute modafinil ingestion on exercise time to exhaustion. *Medicine & Science in Sports & Exercise*, *36*, 1078–1082. doi:10.1249/01.MSS.0000128146.12004.4F

Johnson, M. H., Stewart, J., Humphries, S. A., & Chamove, A. S. (2012). Marathon runners' reaction to potassium iontophoretic experimental pain: pain tolerance, pain threshold, coping and self-efficacy. *European Journal of Pain*, *16*, 767–774. doi:10.1002/j.1532-2149.2011.00059.x

Joinson, A. (1999). Social desirability, anonymity, and internet-based questionnaires. *Behavior Research Methods, Instruments, & Computers*, *31*, 433–438. doi:10.3758/BF03200723

Jones, A. M., & Burnley, M. (2009). Oxygen uptake kinetics: An underappreciated determinant of exercise performance. *International Journal of Sports Physiology and Performance*, *4*, 524–532. Retrieved from http://journals.humankinetics.com/ijspp

Jones, A. M., & Carter, H. (2000). The effect of endurance training on parameters of aerobic fitness. *Sports Medicine*, *29*, 373–386. doi:10.2165/00007256-200029060-00001

Jones, A. M., Vanhatalo, A., Burnley, M., Morton, R. H., & Poole, D. C. (2010). Critical power: Implications for determination of VO2max and exercise tolerance. *Medicine & Science in Sports & Exercise*, *42*, 1876–1890. doi:10.1249/MSS.0b013e3181d9cf7f

Jones, H. S., Williams, E. L., Bridge, C. A., Marchant, D., Midgley, A. W., Micklewright, D., & McNaughton, L. R. (2013). Physiological and psychological effects of deception on pacing strategy and performance: A review. *Sports Medicine*, *43*, 1243–1257. doi:10.1007/s40279-013-0094-1

Jones, M., Meijen, C., McCarthy, P. J., & Sheffield, D. (2009). A Theory of Challenge and Threat States in Athletes. *International Review of Sport and Exercise Psychology*, *2*, 161–180. doi:10.1080/17509840902829331

Jones, M. V, Lane, A. M., Bray, S. R., Uphill, M., & Catlin, J. (2005). Development and validation of the Sport Emotion Questionnaire. *Journal of Sport & Exercise Psychology*, *27*, 407–431. Retrieved from http://journals.humankinetics.com/jsep

Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: the physiology of champions. *The Journal of Physiology*, *586*, 35–44. doi:10.1113/jphysiol.2007.143834

Jung, C., Ferrari, M., Goebel, B., & Figulla, H. R. (2009). The patient’s motivation during bicycle stress ECG test is dependent on the investigator's sex in male patients. *International Journal of Cardiology*, *136*, 348–351. doi:10.1016/j.ijcard.2008.04.074

Karageorghis, C. I., & Priest, D. (2012a). Music in the exercise domain: A review and synthesis (Part I). *International Review of Sport and Exercise Psychology*, *5*, 44–66. doi:10.1080/1750984X.2011.631026

Karageorghis, C. I., & Priest, D. (2012b). Music in the exercise domain: A review and synthesis (Part II). *International Review of Sport and Exercise Psychology*, *5*, 67–84. doi:10.1080/1750984X.2011.631027

Karageorghis, C. I., & Terry, P. C. (1997). The psychophysical effects of music in sport and exercise: A review. *Journal of Sport Behavior*, *20*, 54–68.

Kavanagh, D., & Hausfeld, S. (1986). Physical performance and self-efficacy under happy and sad moods. *Journal of Sport & Exercise Psychology*, *8*, 112–123. Retrieved from http://journals.humankinetics.com/jsep

Keillor, J. M., Barrett, A. M., Crucian, G. P., Kortenkamp, S. A., & Heilman, K. M. (2002). Emotional experience and perception in the absence of facial feedback. *Emotional Experience and Perception in the Absence of Facial Feedback*, *8*, 130–135. doi:10.1017/S1355617702811134

Kellmann, M., Bußmann, G., Anders, D., & Schulte, S. (2006). Psychological aspects of rowing. In J. Dosil (Ed.), *The sport psychologist’s handbook: A guide for sport-specific performance enhancement* (pp. 479–501). Chichester, England: John Wiley & Sons.

Kelly, J., Vanhatalo, A., Wilkerson, D. P., Wylie, L. J., & Jones, A. M. (2013). Effects of nitrate on the power-duration relationship for severe-intensity exercise. *Medicine & Science in Sports & Exercise*, *45*, 1798–1806. doi:10.1249/MSS.0b013e31828e885c

Kerr, Z. Y., Casa, D. J., Marshall, S. W., & Comstock, R. D. (2013). Epidemiology of exertional heat illness among U.S. High School Athletes. *American Journal of Preventive Medicine*, *44*, 8–14. doi:10.1016/j.amepre.2012.09.058

King, M. F., & Bruner, G. C. (2000). Social desirability bias: A neglected aspect of validity testing. *Psychology and Marketing*, *17*, 79–103. doi:10.1002/(SICI)1520-6793(200002)17:2<79::AID-MAR2>3.0.CO;2-0

Kitzinger, J. (1994). The methodology of Focus Groups: the importance of interaction between research participants. *Sociology of Health & Illness*, *16*, 103–121. doi:10.1111/1467-9566.ep11347023

Kitzinger, J. (2006). Focus groups. In C. Pope & N. Mays (Eds.), *Qualitative research in health care* (3rd ed., pp. 21–31). Malden, MA: Blackwell Publishing.

Kleine, D., Sampedro, R. M., & Melo, S. L. (1988). Anxiety and performance in runners: Effects of stress and anxiety on physical performance. *Anxiety Research*, *1*, 235–246.

Knechtle, B., Rüst, C. A., Rosemann, T., & Lepers, R. (2012). Age-related changes in 100-km ultra-marathon running performance. *AGE*, *34*, 1033–1045. doi:10.1007/s11357-011-9290-9

Knechtle, B., Wirth, A., Knechtle, P., & Rosemann, T. (2010). Training volume and personal best time in marathon, not anthropometric parameters, are associated with performance in male 100-km ultrarunners. *Journal of Strength and Conditioning Research*, *24*, 604–609. doi:10.1519/JSC.0b013e3181c7b406

Krane, V., Andersen, M. B., & Strean, W. B. (1997). Issues of qualitative research methods and presentation. *Journal of Sport & Exercise Psychology*, *19*, 213–218. Retrieved from http://journals.humankinetics.com/jsep

Kress, J. L., & Statler, T. (2007). A naturalistic investigation of former Olympic cyclists' cognitive strategies for coping with exertion pain during performance. *Journal of Sport Behavior*, *30*, 428–452.

Kühberger, A., Fritz, A., & Scherndl, T. (2014). Publication bias in psychology: A diagnosis based on the correlation between effect size and sample size. *PloS One*, *9*(9), e105825. doi:10.1371/journal.pone.0105825

Kyllo, L. B., & Landers, D. M. (1995). Goal setting in sport and exercise: A research synthesis to resolve the controversy. *Journal of Sport & Exercise Psychology*, *17*, 117–137. Retrieved from http://journals.humankinetics.com/jsep

LaCaille, R. A., Masters, K. S., & Heath, E. M. (2004). Effects of cognitive strategy and exercise setting on running performance, perceived exertion, affect, and satisfaction. *Psychology of Sport and Exercise*, *5*, 461–476. doi:10.1016/S1469-0292(03)00039-6

Laguna, P. L., & Dobbert, K. (2002). The effect of wearing sunglasses on performance, exercise-induced feeling states, and perceived exertion in runners. *International Journal of Sport Psychology*, *33*, 355–371.

Lane, A. [Andrew]. M., Beedie, C. J., Jones, M. V, Uphill, M., & Devonport, T. J. (2012). The BASES Expert Statement on emotion regulation in sport. *Journal of Sports Sciences*, *30*, 1189–1195. doi:10.1080/02640414.2012.693621

Lane, A. [Andrew]. M., Devonport, T. J., Friesen, A. P., Beedie, C. J., Fullerton, C. L., & Stanley, D. M. (2016). How should I regulate my emotions if I want to run faster? *European Journal of Sport Science*, *16*, 465–472. doi:10.1080/17461391.2015.1080305

Lane, A. [Aoife]., Murphy, N., Bauman, A., & Chey, T. (2012). Active for a day: Predictors of relapse among previously active mass event participants. *Journal of Physical Activity & Health*, *9*, 48–52. Retrieved from http://journals.humankinetics.com/jpah

Lane, A. [Aoife]., Murphy, N. M., & Bauman, A. (2008). *The impact of participation in the Flora Women's Mini Marathon on physical activity behaviour in women. Research Report 1*. Ireland: Centre for Health Behaviour Research, Department of Health Sport and Exercise Sciences, Waterford Institute of Technology and Irish Sports Council.

Lanzetta, J. T., Cartwright-Smith, J., & Kleck, R. E. (1976). Effects of nonverbal dissimulation on emotional experience and autonomic arousal. *Journal of Personality and Social Psychology, 33*, 354–370. doi:10.1037//0022-3514.33.3.354

Larsen, R. J., Kasimatis, M., & Frey, K. (1992). Facilitating the furrowed brow: An unobtrusive test of the facial feedback hypothesis applied to unpleasant affect. *Cognition and Emotion*, *6*, 321–338. doi:10.1080/02699939208409689

Lavallee, D., Kremer, J., Moran, A. P., & Williams, M. (2004). Concentration. In *Sport psychology: Contemporary themes* (pp. 91–117). New York, NY: Palgrave Macmillan.

Lazarus, R. S. (1999). *Stress and emotion*. New York, NY: Springer.

Lazarus, R. S. (2000). How emotions influence performance in competitive sports. *The Sport Psychologist*, *14*, 229–252. Retrieved from http://journals.humankinetics.com/tsp

Le Tour de France 2014 Route. (n.d.). Retrieved from http://www.letour.com/le-tour/2014/us/overall-route.html

Lewis, M. B. (2012). Exploring the positive and negative implications of facial feedback. *Emotion*, *12*, 852–859. doi:10.1037/a0029275

Lind, E., Welch, A. S., & Ekkekakis, P. (2009). Do "mind over muscle" strategies work? Examining the effects of attentional association and dissociation on exertional, affective and physiological responses to exercise. *Sports Medicine*, *39*, 743–764. doi:10.2165/11315120-000000000-00000

Lindsay, P., Maynard, I., & Thomas, O. (2005). Effects of hypnosis on flow states and cycling performance. *The Sport Psychologist*, *19*, 164–177. Retrieved from http://journals.humankinetics.com/tsp

Locke, E. a, & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *The American Psychologist*, *57*, 705–717. doi:10.1037/0003-066X.57.9.705

Lorimer, R., & Babraj, J. (2013). The potential influence of perception of achievement on performance in volitional time-to-exhaustion cycle ergometer trials. *Journal of Strength and Conditioning Research*, *27*, 1546–1548. doi:10.1519/JSC.0b013e318274f1e3

MacMahon, C., Schücker, L., Hagemann, N., & Strauss, B. (2014). Cognitive fatigue effects on physical performance during running. *Journal of Sport & Exercise Psychology*, *36*, 375–381. doi:10.1123/jsep.2013-0249

Malek, M. H., Housh, T. J., Berger, D. E., Coburn, J. W., & Beck, T. W. (2004). A new nonexercise-based VO2max equation for aerobically trained females. *Medicine & Science in Sports & Exercise*, *36*, 1804–1810. doi:10.1249/01.MSS.0000142299.42797.83

Malek, M. H., Housh, T. J., Berger, D. E., Coburn, J. W., & Beck, T. W. (2005). A new non-exercise-based VO2max prediction equation for aerobically trained men. *Journal of*

Strength and Conditioning Research, *19*, 559–565. Retrieved from http://journals.lww.com/nsca-jscr

Mallett, C. J., & Hanrahan, S. J. (1997). Race modeling: An effective cognitive strategy for the 100 m sprinter? *The Sport Psychologist*, *11*, 72–85. Retrieved from http://journals.humankinetics.com/tsp

Marcora, S. (2007). Entia non sunt multiplicanda praeter necessitatem. *The Journal of Physiology*, *578*, 371. doi:10.1113/jphysiol.2006.124370

Marcora, S. (2009). Perception of effort during exercise is independent of afferent feedback from skeletal muscles, heart, and lungs. *Journal of Applied Physiology*, *106*, 2060–2062. doi:10.1152/japplphysiol.90378.2008

Marcora, S. (2010a). Counterpoint: Afferent feedback from fatigued locomotor muscles is not an important determinant of endurance exercise performance. *Journal of Applied Physiology*, *108*, 454–456. doi:10.1152/japplphysiol.00976.2009a

Marcora, S. (2010b). Last Word on Point:Counterpoint: Afferent feedback from fatigued locomotor muscles is not an important determinant of endurance exercise performance. *Journal of Applied Physiology*, *108*, 470. doi:10.1152/japplphysiol.01393.2009

Marcora, S. (2015, December). *The limit to endurance performance: Mind over muscle?* Paper presented at the British Psychological Society Division of Sport and Exercise Psychology Conference, Leeds, England.

Marcora, S. M. (2008). Do we really need a central governor to explain brain regulation of exercise performance? *European Journal of Applied Physiology*, *104*, 929–931. doi:10.1007/s00421-008-0818-3

Marcora, S. M., & Bosio, A. (2007). Effect of exercise-induced muscle damage on endurance running performance in humans. *Scandinavian Journal of Medicine & Science in Sports*, *17*, 662–671. doi:10.1111/j.1600-0838.2006.00627.x

Marcora, S. M., Bosio, A., & de Morree, H. M. (2008). Locomotor muscle fatigue increases cardiorespiratory responses and reduces performance during intense cycling exercise independently from metabolic stress. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology*, *294*, R874–R883. doi:10.1152/ajpregu.00678.2007

Marcora, S. M., & Staiano, W. (2010). The limit to exercise tolerance in humans: mind over muscle? *European Journal of Applied Physiology*, *109*, 763–770. doi:10.1007/s00421-010-1418-6

Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical performance in humans. *Journal of Applied Physiology*, *106*, 857–864. doi:10.1152/japplphysiol.91324.2008

Martin, G. L., Vause, T., & Schwartzman, L. (2005). Experimental studies of psychological interventions with athletes in competitions: Why so few? *Behavior Modification*, *29*, 616–641. doi:10.1177/0145445503259394

Martin, J. J., & Gill, D. L. (1991). The relationships among competitive orientation, sport-confidence, self-efficacy, anxiety, and performance. *Journal of Sport & Exercise Psychology*, *13*, 149–159. Retrieved from http://journals.humankinetics.com/jsep

Martin, S. B., Bochum, R., Lavallee, D., & Page, S. J. (2002). Development and psychometric evaluation of the Sport Psychology Attitudes - Revised Form: A multiple group investigation. *The Sport Psychologist*, *16*, 272–290. Retrieved from http://journals.humankinetics.com/tsp

Martinent, G., & Ferrand, C. (2009). A naturalistic study of the directional interpretation process of discrete emotions during high-stakes table tennis matches. *Journal of Sport & Exercise Psychology*, *31*, 318–336. Retrieved from http://journals.humankinetics.com/jsep

Martinent, G., & Ferrand, C. (2015). A field study of discrete emotions: Athletes' cognitive appraisals during competition. *Research Quarterly for Exercise and Sport*, *86*(1), 51–62. doi:10.1080/02701367.2014.975176

Masters, K. S., & Ogles, B. M. (1998). Associative and dissociative cognitive strategies in exercise and running: 20 years later, what do we know? *The Sport Psychologist*, *12*, 253–270. Retrieved from http://journals.humankinetics.com/tsp

Mauger, A. R. (2014). Factors affecting the regulation of pacing: current perspectives. *Open Access Journal of Sports Medicine*, *5*, 209–214. doi:10.2147/OAJSM.S38599

Mauger, A. R., Jones, A. M., & Williams, C. A. (2010). Influence of acetaminophen on performance during time trial cycling. *Journal of Applied Physiology*, *108*, 98–104. doi:10.1152/japplphysiol.00761.2009

Mauger, A. R., Jones, A. M., & Williams, C. A. (2011). The effect of non-contingent and accurate performance feedback on pacing and time trial performance in 4-km track cycling. *British Journal of Sports Medicine*, *45*, 225–229. doi:10.1136/bjsm.2009.062844

McCann, S. (2011). At the Olympics, everything is a performance issue. *International Journal of Sport and Exercise Psychology*, *6*, 267–276. doi:10.1080/1612197X.2008.9671871

McKay, J., Niven, A. G., Lavallee, D., & White, A. (2008). Sources of strain among elite UK track athletes. *The Sport Psychologist*, *22*, 143–163. Retrieved from http://journals.humankinetics.com/tsp

Meijen, C., Day, C., & Hays, K. F. (2016). Running a psyching team: Providing mental support at long-distance running events. *Journal of Sport Psychology in Action*. doi:10.1080/21520704.2016.1205697

Mellalieu, S. D., Neil, R., Hanton, S., & Fletcher, D. (2009). Competition stress in sport performers: Stressors experienced in the competition environment. *Journal of Sports Sciences*, *27*, 729–744. doi:10.1080/02640410902889834

Metsios, G. S., Flouris, A. D., Koutedakis, Y., & Theodorakis, Y. (2006). The effect of performance feedback on cardiorespiratory fitness field tests. *Journal of Science and Medicine in Sport*, *9*, 263–266. doi:10.1016/j.jsams.2006.03.027

Michie, S., & Prestwich, A. (2010). Are interventions theory-based? Development of a theory coding scheme. *Health Psychology*, *29*, 1–8. doi:10.1037/a0016939

Micklewright, D., & Parry, D. (2010). The central governor model cannot be adequately tested by observing its components in isolation. *Sports Medicine*, *40*, 91–94. doi:10.2165/11531360-000000000-00000

Miles, A. J., Neil, R., & Barker, J. (2016). Preparing to take the field: A temporal exploration of stress, emotion, and coping in elite cricket. *The Sport Psychologist*, *30*, 101–112. doi:10.1123/tsp.2014-0142

Miller, A., & Donohue, B. (2003). The development and controlled evaluation of athletic mental preparation strategies in high school distance runners. *Journal of Applied Sport Psychology*, *15*, 321–334. doi:10.1080/714044200

Miller, M. (1993). Efficacy strength and performance in competitive swimmers of different skill levels. *International Journal of Sport Psychology*, *24*, 284–296.

Moffatt, R. J., Chitwood, L. F., & Biggerstaff, K. D. (1994). The influence of verbal encouragement during assessment of maximal oxygen uptake. *The Journal of Sports Medicine and Physical Fitness*, *34*, 45–49.

Moore, L. J., Vine, S. J., Wilson, M. R., & Freeman, P. (2012). The effect of challenge and threat states on performance: An examination of potential mechanisms. *Psychophysiology*, *49*, 1417–1425. doi:10.1111/j.1469-8986.2012.01449.x

Moore, L. J., Wilson, M. R., Vine, S. J., Coussens, A. H., & Freeman, P. (2013). Champ or chump? Challenge and threat states during pressurized competition. *Journal of Sport & Exercise Psychology*, *35*, 551–562. Retrieved from http://journals.humankinetics.com/jsep

Morgan, W. P., Hirta, K., Weitz, G. A., & Balke, B. (1976). Hypnotic perturbation of perceived exertion: Ventilatory consequences. *American Journal of Clinical Hypnosis*, *18*, 182–190. doi:10.1080/00029157.1976.10403796

Morgan, W. P., Horstman, D. H., Cymerman, A., & Stokes, J. (1983). Facilitation of physical performance by means of a cognitive strategy. *Cognitive Therapy and Research*, *7*, 251–264. doi:10.1007/BF01205139

Morgan, W. P., & Pollock, M. L. (1977). Psychologic characterization of the elite distance runner. *Annals of the New York Academy of Sciences*, *301*, 382–403. doi:10.1111/j.1749-6632.1977.tb38215.x

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organizational Research Methods*, *11*, 364–386. doi:10.1177/1094428106291059

Morton, R. H. (2009). Deception by manipulating the clock calibration influences cycle ergometer endurance time in males. *Journal of Science and Medicine in Sport*, *12*, 332–337. doi:10.1016/j.jsams.2007.11.006

Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-control as limited resource: regulatory depletion patterns. *Journal of Personality and Social Psychology*, *74*, 774–789. doi:10.1037/0022-3514.74.3.774

Murgatroyd, S. R., Wylde, L. A., Cannon, D. T., Ward, S. A., & Rossiter, H. B. (2014). A “ramp-sprint” protocol to characterise indices of aerobic function and exercise intensity domains in a single laboratory test. *European Journal of Applied Physiology*, *114*, 1863–1874. doi:10.1007/s00421-014-2908-8

Nederhof, A. J. (1985). Methods of coping with social desirability bias: a review. *European Journal of Social Psychology*, *15*, 263–280. doi:10.1002/ejsp.2420150303

Neil, R., Bowles, H. C. R., Fleming, S., & Hanton, S. (2016). The experience of competition stress and emotions in cricket. *The Sport Psychologist*, *30*, 76–88. doi:10.1123/tsp.2014-0077

Neil, R., Hanton, S., & Mellalieu, S. D. (2013). Seeing things in a different light: Assessing the effects of a cognitive-behavioral intervention upon the further appraisals and performance of golfers. *Journal of Applied Sport Psychology*, *25*, 106–130. doi:10.1080/10413200.2012.658901

Neil, R., Hanton, S., Mellalieu, S. D., & Fletcher, D. (2011). Competition stress and emotions in sport performers: The role of further appraisals. *Psychology of Sport and Exercise*, *12*, 460–470. doi:10.1016/j.psychsport.2011.02.001

Nicholls, A. R., Levy, A. R., Grice, A., & Polman, R. C. J. (2009). Stress appraisals, coping, and coping effectiveness among international cross-country runners during training and competition. *European Journal of Sport Science*, *9*, 285–293. doi:10.1080/17461390902836049

Niedenthal, P. M., Barsalou, L. W., Ric, F., & Krauth-Gruber, S. (2005). Embodiment in the acquisition and use of emotion language. In L. F. Barrett, P. M. Niedenthal, & P. Winkielman (Eds.), *Emotion and consciousness* (pp. 21–50). New York, NY: Guilford Press.

Noakes, T. D. (2012). Fatigue is a brain-derived emotion that regulates the exercise behavior to ensure the protection of whole body homeostasis. *Frontiers in Physiology*, *3*, 82. doi:10.3389/fphys.2012.00082

Noble, B. J., & Noble, J. M. (2000). Perception of effort during endurance training and performance. In R. J. Shephard & P.-O. Åstrand (Eds.), *Endurance in sport* (2nd ed., pp. 374–394). Oxford, England: Blackwell Science.

Noble, B. J., & Robertson, R. J. (1996a). The Borg Scale: Development, administration, and experimental use. In *Perceived exertion* (pp. 59–92). Champaign, IL: Human Kinetics.

Noble, B. J., & Robertson, R. J. (1996b). The influence of psychological factors on the setting of perceived exertion: Psychophysiological modeling. In *Perceived exertion* (pp. 171–195). Champaign, IL: Human Kinetics.

Noblet, A. J., & Gifford, S. M. (2002). The sources of stress experienced by professional Australian footballers. *Journal of Applied Sport Psychology*, *14*, 1–13. doi:10.1080/10413200209339007

Okwumabua, T. M., Meyers, A. W., Schleser, R., & Cooke, C. J. (1983). Cognitive strategies and running performance: An exploratory study. *Cognitive Therapy and Research*, *7*, 363–369. doi:10.1007/BF01177558

Olds, T. S., Norton, K. I., & Craig, N. P. (1993). Mathematical model of cycling performance. *Journal of Applied Physiology*, *75*, 730–737. Retrieved from http://jap.physiology.org/

Oliver, S. J., Costa, R. J. S., Walsh, N. P., Laing, S. J., & Bilzon, J. L. J. (2009). One night of sleep deprivation decreases treadmill endurance performance. *European Journal of Applied Physiology*, *107*, 155–161. doi:10.1007/s00421-009-1103-9

Onwuegbuzie, A. J., & Leech, N. L. (2005). On becoming a pragmatic researcher: The importance of combining quantitative and qualitative research methodologies.

International Journal of Social Research Methodology, *8*, 375–387. doi:10.1080/13645570500402447

Özyener, F., Whipp, B. J., & Ward, S. A. (2012). The contribution of "resting" body muscles to the slow component of pulmonary oxygen uptake during high-intensity cycling. *Journal of Sports Science and Medicine, 11*, 759–767. Retrieved from http://www.jssm.org/

Padgett, V. R., & Hill, A. K. (1989). Maximizing athletic performance in endurance events: A comparison of cognitive strategies. *Journal of Applied Social Psychology*, *19*, 331–340. doi:10.1111/j.1559-1816.1989.tb00058.x

Page, J., & Thelwell, R. (2013). The value of social validation in single-case methods in sport and exercise psychology. *Journal of Applied Sport Psychology*, *25*, 61–71. doi:10.1080/10413200.2012.663859

Pageaux, B. (2014). The psychobiological model of endurance performance: An effort-based decision-making theory to explain self-paced endurance performance. *Sports Medicine*. doi:10.1007/s40279-014-0198-2

Pageaux, B. (2016). Perception of effort in Exercise Science: Definition, measurement and perspectives. *European Journal of Sport Science*. doi:10.1080/17461391.2016.1188992

Pageaux, B., Lepers, R., Dietz, K. C., & Marcora, S. M. (2014). Response inhibition impairs subsequent self-paced endurance performance. *European Journal of Applied Physiology, 114*, 1095–1105. doi:10.1007/s00421-014-2838-5

Palmer, G. S., Borghouts, L. B., Noakes, T. D., & Hawley, J. A. (1999). Metabolic and performance responses to constant-load vs. variable-intensity exercise in trained cyclists. *Journal of Applied Physiology*, *87*, 1186–1196. Retrieved from http://jap.physiology.org/

Papaioannou, A., Ballon, F., Theodorakis, Y., & Auwelle, Y. V. (2004). Combined effect of goal setting and self-talk in performance of a soccer-shooting task. *Perceptual and Motor Skills*, *98*, 89–99. doi:10.2466/PMS.98.1.89-99

Patrick, T. D., & Hrycaiko, D. W. (1998). Effects of a mental training package on an endurance performance. *The Sport Psychologist*, *12*, 283–299. Retrieved from http://journals.humankinetics.com/tsp

Patton, M. Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Pavlidou, M., & Doganis, G. (2008). The effects of a psychological intervention program in swimming. *Journal of Excellence*, *12*, 71–77.

Pennebaker, J. W., & Lightner, J. M. (1980). Competition of internal and external information in an exercise setting. *Journal of Personality and Social Psychology*, *39*, 165–174. doi:10.1037//0022-3514.39.1.165

Perreault, S., Vallerand, R. J., Montgomery, D., & Provencher, P. (1998). Coming from behind: On the effect of psychological momentum on sport performance. *Journal of Sport & Exercise Psychology*, *20*, 421–436. Retrieved from http://journals.humankinetics.com/jsep

Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences: A practical guide*. Oxford, England: Blackwell Publishing.

Peveler, W. W., & Green, M. (2010). The effect of extrinsic factors on simulated 20-km time trial performance. *Journal of Strength and Conditioning Research*, *24*, 3265–3269. doi:10.1519/JSC.0b013e3181b2c817

Philippen, P. B., Bakker, F. C., Oudejans, R. R. D., & Canal-Bruland, R. (2012). The effects of smiling and frowning on perceived affect and exertion while physically active. *Journal of Sport Behavior*, *35*, 337–353.

Pitsiladis, Y. P., Onywera, V. O., Geogiades, E., O'Connell, W., & Boit, M. K. (2004). The dominance of Kenyans in distance running. *Equine and Comparative Exercise Physiology*, *1*, 285–291. doi:10.1079/ECP200433

Popper, K. R. (1959). *The logic of scientific discovery*. London, England: Hutchinson.

Post, P., Muncie, S., & Simpson, D. (2012). The effects of imagery training on swimming performance: An applied investigation. *Journal of Applied Sport Psychology*, *24*, 323–337. doi:10.1080/10413200.2011.643442

Rejeski, W. J. (1985). Perceived Exertion: An active or passive process? *Journal of Sport & Exercise Psychology*, *7*, 371–378. Retrieved from http://journals.humankinetics.com/jsep

Rendi, M., Szabo, A., & Szabó, T. (2008). Performance enhancement with music in rowing sprint. *The Sport Psychologist*, *22*, 175–182. Retrieved from http://journals.humankinetics.com/tsp

Renfree, A., Martin, L., Micklewright, D., & St Clair Gibson, A. (2014). Application of decision-making theory to the regulation of muscular work rate during self-paced competitive endurance activity. *Sports Medicine*, *44*, 147–158. doi:10.1007/s40279-013-0107-0

Renfree, A., West, J., Corbett, M., Rhoden, C., & St Clair Gibson, A. (2012). Complex interplay between determinants of pacing and performance during 20-km cycle time trials. *International Journal of Sports Physiology and Performance*, *7*, 121–129. Retrieved from http://journals.humankinetics.com/ijspp

Richards, J., Thorogood, M., Hillsdon, M., & Foster, C. (2013). Face-to-face versus remote and web 2.0 interventions for promoting physical activity. *The Cochrane Database of Systematic Reviews*, *9*, CD010393. doi:10.1002/14651858.CD010393.pub2

Rushall, B. S., Hall, M., Roux, L., Sasseville, J., & Rushall, A. C. (1988). Effects of three types of thought content instructions on skiing performance. *The Sport Psychologist*, *2*, 283–297. Retrieved from http://journals.humankinetics.com/tsp

Rushall, B. S., & Shewchuk, M. L. (1989). Effects of thought content instructions on swimming performance. *The Journal of Sports Medicine and Physical Fitness*, *29*, 326–334.

Russell, R. D., Redmann, S. M., Ravussin, E., Hunter, G. R., & Larson-Meyer, D. E. (2004). Reproducibility of endurance performance on a treadmill using a preloaded time trial. *Medicine & Science in Sports & Exercise*, *36*, 717–724. doi:10.1249/01.MSS.0000121954.95892.C8

Ryan, R. M., Frederick, C. M., Lepes, D., Rubio, N., & Sheldon, K. M. (1997). Intrinsic motivation and exercise adherence. *International Journal of Sport Psychology*, *28*, 335–354.

Saintsing, D. E., Richman, C. L., & Bergey, D. B. (1988). Effects of three cognitive strategies on long-distance running. *Bulletin of the Psychonomic Society*, *26*, 34–36. doi:10.3758/BF03334853

Salmon, P., Hanneman, S., & Harwood, B. (2010). Associative / dissociative cognitive strategies in sustained physical activity: Literature review and proposal for a mindfulness-based conceptual model. *The Sport Psychologist, 24,* 127–156. Retrieved from http://journals.humankinetics.com/tsp

Samson, A., Simpson, D., Kamphoff, C., & Langlier, A. (2015). Think aloud: An examination of distance runners ' thought processes. *International Journal of Sport and Exercise Psychology,* 1–14. doi:10.1080/1612197X.2015.1069877

Sarkar, M., & Fletcher, D. (2014). Psychological resilience in sport performers: a review of stressors and protective factors. *Journal of Sports Sciences, 32,* 1419–1434. doi:10.1080/02640414.2014.901551

Scanlan, T. K., Stein, G. L., & Ravizza, K. (1991). An in-depth study of former elite figure skaters: III. Sources of stress. *Journal of Sport & Exercise Psychology, 13,* 103–120. Retrieved from http://journals.humankinetics.com/jsep

Schneider, M., Dunn, A., & Cooper, D. (2009). Affect, exercise, and physical activity among healthy adolescents. *Journal of Sport & Exercise Psychology*, *31*, 706–723. Retrieved from http://journals.humankinetics.com/jsep

Schomer, H. H. (1987). Mental strategy training programme for marathon runners. *International Journal of Sport Psychology*, *18*, 133–151.

Schücker, L., Anheier, W., Hagemann, N., Strauss, B., & Völker, K. (2013). On the optimal focus of attention for efficient running at high intensity. *Sport, Exercise, and Performance Psychology*, *2*, 207–219. doi:10.1037/a0031959

Schücker, L., Hagemann, N., Strauss, B., & Völker, K. (2009). The effect of attentional focus on running economy. *Journal of Sports Sciences*, *27*, 1241–1248. doi:10.1080/02640410903150467

Schüler, J., & Langens, T. A. (2007). Psychological crisis in a marathon and the buffering effects of self-verbalizations. *Journal of Applied Social Psychology*, *37*, 2319–2344. doi:10.1111/j.1559-1816.2007.00260.x

Schumacher, J. M., Becker, A. J., & Wiersma, L. D. (2016). Forging ahead: An examination of the experiences and coping mechanisms of channel swimmers. *The Sport Psychologist*. doi:10.1123/tsp.2015-0137

Schumacher, Y. O., & Mueller, P. (2002). The 4000-m team pursuit cycling world record: theoretical and practical aspects. *Medicine & Science in Sports & Exercise*, *34*, 1029–1036. doi:10.1097/00005768-200206000-00020

Scott, J. P. R., McNaughton, L. R., & Polman, R. C. J. (2006). Effects of sleep deprivation and exercise on cognitive, motor performance and mood. *Physiology & Behavior*, *87*, 396–408. doi:10.1016/j.physbeh.2005.11.009

Scott, L. M., Scott, D., Bedic, S. P., & Dowd, J. (1999). The effect of associative and dissociative strategies on rowing ergometer performance. *The Sport Psychologist*, *13*, 57–68. Retrieved from http://journals.humankinetics.com/tsp

Scott, V., & Gijsbers, K. (1981). Pain perception in competitive swimmers. *British Medical Journal*, *283*, 91–93. doi:10.1136/bmj.284.6309.117

Scruggs, T. E., & Mastropieri, M. A. (2001). How to summarize single-participant research: Ideas and applications. *Exceptionality: A Special Education Journal*, *9*, 227–244. doi:10.1207/S15327035EX0904_5

Sewell, D. F. (1996). Attention-focusing instructions and training times in competitive youth swimmers. *Perceptual and Motor Skills*, *83*, 915–920. doi:10.2466/pms.1996.83.3.915

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston, MA: Houghton Mifflin.

Sheard, M., & Golby, J. (2006). Effect of a psychological skills training program on swimming performance and positive psychological development. *International Journal of Sport and Exercise Psychology*, *4*, 149–169. doi:10.1080/1612197X.2006.9671790

Shephard, R. J. (2009). Is it time to retire the "Central Governor"? *Sports Medicine*, *39*, 709–721. doi:10.2165/11315130-000000000-00000

Shephard, R. J., & Åstrand, P.-O. (Eds.). (2000). *Endurance in sport* (2nd ed.). Oxford, England: Blackwell Science.

Simons, J. (2012). Endurance psychology. In I. Mujika (Ed.), *Endurance training – Science and practice* (pp. 201–210). Vitoria-Gasteiz, Basque Country: Iñigo Mujika S.L.U.

Simpson, D., Post, P. G., & Tashman, L. S. (2013). Adventure Racing: The experiences of participants in the Everglades Challenge. *Journal of Humanistic Psychology*, *54*, 113–128. doi:10.1177/0022167813482188

Simpson, D., Post, P. G., Young, G., & Jensen, P. R. (2014). "It's not about taking the easy road": The experiences of ultramarathon runners. *The Sport Psychologist*, *28*, 176–185. doi:10.1123/tsp.2013-0064

Sir Bradley Wiggins hour record attempt: as it happened. (2015). Retrieved from http://www.telegraph.co.uk/sport/othersports/cycling/bradley-wiggins/11643442/Sir-Bradley-Wiggins-hour-record-attempt-live.html

Smirmaul, B. P. C., Dantas, J. L., Nakamura, F. Y., & Pereira, G. (2013). The psychobiological model: A new explanation to intensity regulation and (in)tolerance in endurance exercise. *Revista Brasileira de Educação Física E Esporte*, *27*, 333–340. doi:10.1590/S1807-55092013005000008

Smirmaul, B. P. C., dos Santos, R. V, & da Silva Neto, L. V. (2015). Pre-task music improves swimming performance. *The Journal of Sports Medicine and Physical Fitness*, *55*, 1445–1451.

Smith, J. A., Hauenstein, N. M. A., & Buchanan, L. B. (1996). Goal setting and exercise performance. *Human Performance*, *9*, 141–154. doi:10.1207/s15327043hup0902_3

Smith, M. R., Coutts, A. J., Merlini, M., Deprez, D., Lenoir, M., & Marcora, S. M. (2016). Mental fatigue impairs soccer-specific physical and technical performance. *Medicine & Science in Sports & Exercise*, *48*, 267–276. doi:10.1249/MSS.0000000000000762

Sorrentino, R. M., & Sheppard, B. H. (1978). Effects of affiliation-related motives on swimmers in individual versus group competition: A field experiment. *Journal of Personality and Social Psychology*, *36*, 704–714. doi:10.1037//0022-3514.36.7.704

Spink, K. S., & Longhurst, K. (1986). Cognitive strategies and swimming performances: An exploratory study. *Australian Journal of Science and Medicine in Sport*, *18*, 9–13.

Stanley, D. M., Lane, A. M., Beedie, C. J., Friesen, A. P., & Devonport, T. J. (2012). Emotion regulation strategies used in the hour before running. *International Journal of Sport and Exercise Psychology, 10*, 159–171. doi:10.1080/1612197X.2012.671910

Stepper, S., & Strack, F. (1993). Proprioceptive determinants of emotional and nonemotional feelings. *Journal of Personality and Social Psychology*, *64,* 211–220. doi:10.1037/0022-3514.64.2.211

Stern, C., Cole, S., Gollwitzer, P. M., Oettingen, G., & Balcetis, E. (2013). Effects of implementation intentions on anxiety, perceived proximity, and motor performance. *Personality and Social Psychology Bulletin*, *39*, 623–635. doi:10.1177/0146167213479612

Stevinson, C. D., & Biddle, S. J. H. (1998). Cognitive orientations in marathon running and "hitting the wall." *British Journal of Sports Medicine*, *32*, 229–234. doi:10.1136/bjsm.32.3.229

Stevinson, C. D., & Biddle, S. J. H. (1999). Cognitive strategies in running: A response to Masters and Ogles (1998). *The Sport Psychologist*, *13*, 235–236. Retrieved from http://journals.humankinetics.com/tsp

Stoate, I., Wulf, G., & Lewthwaite, R. (2012). Enhanced expectancies improve movement efficiency in runners. *Journal of Sports Sciences*, *30*, 815–823. doi:10.1080/02640414.2012.671533

Stoeber, J., Uphill, M. A., & Hotham, S. (2009). Predicting race performance in triathlon: The role of perfectionism, achievement goals, and personal goal setting. *Journal of Sport & Exercise Psychology*, *31*, 211–245. Retrieved from http://journals.humankinetics.com/jsep

Stone, M. R., Thomas, K., Wilkinson, M., Jones, A. M., St Clair Gibson, A., & Thompson, K. G. (2012). Effects of deception on exercise performance: Implications for determinants of fatigue in humans. *Medicine & Science in Sports & Exercise*, *44*, 534–541. doi:10.1249/MSS.0b013e318232cf77

Støren, O., Helgerud, J., Støa, E. M., & Hoff, J. (2008). Maximal strength training improves running economy in distance runners. *Medicine & Science in Sports & Exercise*, *40,* 1089–1094. doi:10.1249/MSS.0b013e318168da2f

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile: A nonobtrusive test of the facial feedback hypothesis. *Journal of Personality and Social Psychology*, *54,* 768–777. doi:10.1037/0022-3514.54.5.768

Tassinary, L. G., Cacioppo, J. T., & Geen, T. R. (1989). A psychometric study of surface electrode placements for facial electromyographic recording: I. The brow and cheek muscle regions. *Psychophysiology*. doi:10.1111/j.1469-8986.1989.tb03125.x

Tassinary, L. G., Cacioppo, J. T., & Vanman, E. J. (2007). The skeletomotor system: Surface electromyography. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (3rd ed., pp. 267–300). Cambridge, England: Cambridge University Press.

Tate, A. R., Gennings, C., Hoffman, R. A., Strittmatter, A. P., & Retchin, S. M. (2012). Effects of bone-conducted music on swimming performance. *Journal of Strength and Conditioning Research*, *26*, 982–988. doi:10.1519/JSC.0b013e31822dcdaf

Taylor, J. (1995). A conceptual model for integrating athletes' needs and sport demands in the development of competitive mental preparation strategies. *The Sport Psychologist*, *9*, 339–357. Retrieved from http://journals.humankinetics.com/tsp

Taylor, J., & Kress, J. (2006). Psychology of cycling. In J. Dosil (Ed.), *The sport psychologist's handbook: A guide for sport-specific performance enhancement* (pp. 325–350). Chichester, England: John Wiley & Sons.

Tenenbaum, G. (2001). A social-cognitive perspective of perceived exertion and exertion tolerance. In N. Singer, H. A. Hausenblas, & C. M. Janelle (Eds.), *Handbook of Sport Psychology* (2nd ed., pp. 810–820). New York, NY: Wiley.

Tenenbaum, G., & Connolly, C. T. (2008). Attention allocation under varied workload and effort perception in rowers. *Psychology of Sport and Exercise*, *9*, 704–717. doi:10.1016/j.psychsport.2007.09.002

Tenenbaum, G., Spence, R., & Christensen, S. (1999). The effect of goal difficulty and goal orientation on running performance in young female athletes. *Australian Journal of Psychology*, *51*, 6–11. doi:10.1080/00049539908255328

Terry, P. C., Karageorghis, C. I., Saha, A. M., & D'Auria, S. (2012). Effects of synchronous music on treadmill running among elite triathletes. *Journal of Science and Medicine in Sport*, *15*, 52–57. doi:10.1016/j.jsams.2011.06.003

Terry, P. C., Lane, A. M., Lane, H. J., & Keohane, L. (1999). Development and validation of a mood measure for adolescents. *Journal of Sports Sciences*, *17*, 861–872. doi:10.1080/026404199365425

Tesarz, J., Schuster, A. K., Hartmann, M., Gerhardt, A., & Eich, W. (2012). Pain perception in athletes compared to normally active controls: A systematic review with meta-analysis. *Pain*, *153*, 1253–1262. doi:10.1016/j.pain.2012.03.005

The event. (n.d.). Retrieved from http://www.thelondontriathlon.com/About

The Self-Transcendence 3100 Mile Race. (n.d.). Retrieved from http://3100.srichinmoyraces.org/main-3100

Thelwell, R. C., & Greenlees, I. A. (2001). The effects of a mental skills training package on gymnasium triathlon performance. *The Sport Psychologist*, *15*, 127–141. Retrieved from http://journals.humankinetics.com/tsp

Thelwell, R. C., & Greenlees, I. A. (2003). Developing competitive endurance performance using mental skills training. *The Sport Psychologist*, *17*, 318–337. Retrieved from http://journals.humankinetics.com/tsp

Thelwell, R. C., Weston, N. J. V, & Greenlees, I. a. (2007). Batting on a sticky wicket: Identifying sources of stress and associated coping strategies for professional cricket batsmen. *Psychology of Sport and Exercise*, *8*, 219–232. doi:10.1016/j.psychsport.2006.04.002

Theodorakis, Y. (1995). Effects of self-efficacy, satisfaction, and personal goals on swimming performance. *The Sport Psychologist*, *9*, 245–253. Retrieved from http://journals.humankinetics.com/tsp

Theodorakis, Y., Hatzigeorgiadis, A., & Chroni, S. (2008). Self-Talk: It works, but how? Development and preliminary validation of the Functions of Self-Talk Questionnaire. *Measurement in Physical Education and Exercise Science, 12,* 10–30. doi:10.1080/10913670701715158

Theodorakis, Y., Laparidis, K., & Kioumourtzoglou, E. (1998). Combined effects of goal setting and performance feedback on performance and physiological response on a maximum effort task. *Perceptual and Motor Skills*, *86*, 1035–1041. doi:10.2466/pms.1998.86.3.1035

Thomas, B. H., Ciliska, D., Dobbins, M., & Micucci, S. (2004). A process for systematically reviewing the literature: Providing the research evidence for public health nursing interventions. *Worldviews on Evidence-Based Nursing, 1,* 176–184. doi:10.1111/j.1524-475X.2004.04006.x

Thomas, G., & Renfree, A. (2010). The effect of secret clock manipulation on 10km cycle time trial performance. *International Journal of Arts and Sciences, 3,* 193–202. Retrieved from http://www.internationaljournal.org/

Thompson, R. W., Kaufman, K. A., De Petrillo, L. A., Glass, C. R., & Arnkoff, D. B. (2011). One year follow-up of Mindful Sport Performance Enhancement (MSPE) with archers, golfers, and runners. *Journal of Clinical Sport Psychology*, *5*, 99–116. Retrieved from http://journals.humankinetics.com/jcsp

Tod, D., Hardy, J., & Oliver, E. (2011). Effects of self-talk: A systematic review. *Journal of Sport & Exercise Psychology, 33,* 666–687. Retrieved from http://journals.humankinetics.com/jsep

Triplett, N. (1898). The dynamogenic factors in pacemaking and competition. *American Journal of Psychology*, *9*, 507–533. doi:10.2307/1412188

Tucker, R. (2009). The anticipatory regulation of performance: the physiological basis for pacing strategies and the development of a perception-based model for exercise performance. *British Journal of Sports Medicine, 43,* 392–400. doi:10.1136/bjsm.2008.050799

Tucker, R., Kayser, B., Rae, E., Rauch, L., Bosch, A., & Noakes, T. (2007). Hyperoxia improves 20 km cycling time trial performance by increasing muscle activation levels while perceived exertion stays the same. *European Journal of Applied Physiology*, *101*, 771–781. doi:10.1007/s00421-007-0458-z

Tuffey, S. (2000). Psychological preparation of endurance performers. In R. J. Shephard & P.-O. Åstrand (Eds.), *Endurance in sports* (2nd ed., pp. 451–457). Oxford, England: Blackwell Science.

Uphill, M. A., & Jones, M. V. (2007). Antecedents of emotions in elite athletes. *Research Quarterly for Exercise and Sport*, *78*(2), 79–89. doi:10.1080/02701367.2007.10599406

van Boxtel, A., & Jessurun, M. (1993). Amplitude and bilateral coherency of facial and jaw-elevator EMG activity as an index of effort during a two-choice serial reaction task. *Psychophysiology*, *30,* 589–604. doi:10.1111/j.1469-8986.1993.tb02085.x

Van Raalte, J. L., Morrey, R. B., Cornelius, A. E., & Brewer, B. W. (2015). Self-Talk of marathon runners. *The Sport Psychologist*, *29*, 258–260. doi:10.1123/tsp.2014-0159

Vast, R. L., Young, R. L., & Thomas, P. R. (2010). Emotions in sport: Perceived effects on attention, concentration, and performance. *Australian Psychologist*, *45*, 132–140. doi:10.1080/00050060903261538

Viru, M., Hackney, A. C., Karelson, K., Janson, T., Kuus, M., & Viru, A. (2010). Competition effects on physiological responses to exercise: Performance, cardiorespiratory and hormonal factors. *Acta Physiologica Hungarica*, *97*, 22–30. doi:10.1556/APhysiol.97.2010.1.3

Wagstaff, C. R. D. (2014). Emotion regulation and sport performance. *Journal of Sport & Exercise Psychology*, *36*, 401–412. doi:10.1123/jsep.2013-0257

Wanlin, C. M., Hrycaiko, D. W., Martin, G. L., & Mahon, M. (1997). The effects of a goal-setting package on the performance of speed skaters. *Journal of Applied Sport Psychology*, *9*, 212–228. doi:10.1080/10413209708406483

Waterink, W., & van Boxtel, A. (1994). Facial and jaw-elevator EMG activity in relation to changes in performance level during a sustained information processing task. *Biological Psychology*, *37*, 183–198. doi:10.1016/0301-0511(94)90001-9

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*, 1063–1070. doi:10.1037/0022-3514.54.6.1063

Webb, T. L., Miles, E., & Sheeran, P. (2012). Dealing with feeling: A meta-analysis of the effectiveness of strategies derived from the process model of emotion regulation. *Psychological Bulletin*, *138*, 775–808. doi:10.1037/a0027600

Weinberg, R., Bruya, L., & Jackson, A. (1990). Goal setting and competition: A reaction to Hall and Byrne. *Journal of Sport & Exercise Psychology*, *12*, 92–97. Retrieved from http://journals.humankinetics.com/jsep

Weinberg, R., Gould, D., & Jackson, A. (1979). Expectations and performance: An empirical test of Bandura's self-efficacy theory. *Journal of Sport Psychology*, *1*, 320–331. Retrieved from http://journals.humankinetics.com/jsep

Weinberg, R., Miller, A., & Horn, T. (2012). The influence of a self-talk intervention on collegiate cross-country runners. *International Journal of Sport and Exercise Psychology*, *10*, 123–134. doi:10.1080/1612197X.2012.645135

Weinberg, R., Neff, R., & Jurica, B. (2012). Online mental training: Making it available for the masses. *Journal of Sport Psychology in Action*, *3*, 182–192. doi:10.1080/21520704.2012.656833

Weinberg, R. S., Gould, D., & Jackson, A. (1980). Cognition and motor performance: Effect of psyching-up strategies on three motor tasks. *Cognitive Therapy and Research*, *4*, 239–245. doi:10.1007/BF01173655

Weinberg, R. S., Smith, J., Jackson, A., & Gould, D. (1984). Effect of association, dissociation, and positive self-talk strategies on endurance performance. *Canadian Journal of Applied Sport Sciences*, *9*, 25–32.

Whipp, B. J., Davis, J. A., Torres, F., & Wasserman, K. (1981). A test to determine parameters of aerobic function during exercise. *Journal of Applied Physiology*, *50*, 217–221. Retrieved from http://jap.physiology.org/

Whitmarsh, B. G., & Alderman, R. B. (1993). Role of psychological skills training in increasing athletic pain tolerance. *The Sport Psychologist*, *7*, 388–399. Retrieved from http://journals.humankinetics.com/TSP

Wilber, R. L., & Pitsiladis, Y. P. (2012). Kenyan and Ethiopian distance runners: What makes them so good? *International Journal of Sports Physiology and Performance*, *7*, 92–102. Retrieved from http://journals.humankinetics.com/journal/ijspp

Wilkinson, D. M., Fallowfield, J. L., & Myers, S. D. (1999). A modified incremental shuttle run test for the determination of peak shuttle running speed and the prediction of maximal oxygen uptake. *Journal of Sports Sciences*, *17*, 413–419. doi:10.1080/026404199365939

Williams, E. L., Jones, H. S., Sparks, S. A., Marchant, D. C., Midgley, A. W., & McNaughton, L. R. (2015). Competitor presence reduces internal attentional focus and improves 16.1km cycling time trial performance. *Journal of Science and Medicine in Sport*, *18*, 486–491. doi:10.1016/j.jsams.2014.07.003

Williams, K. D., Nida, S. A., Baca, L. D., & Latané, B. (1989). Social loafing and swimming: Effects of identifiability on individual and relay performance of intercollegiate swimmers. *Basic and Applied Social Psychology*, *10*, 73–81. doi:10.1207/s15324834basp1001_7

Williams, L. (2013). Commitment to sport and exercise: Re-examining the literature for a practical and parsimonious model. *Journal of Preventive Medicine and Public Health*, *46*, S35–42. doi:10.3961/jpmph.2013.46.S.S35

Williams, S. E., Cumming, J., & Balanos, G. M. (2010). The use of imagery to manipulate challenge and threat appraisal States in athletes. *Journal of Sport & Exercise Psychology*, *32*, 339–358. Retrieved from http://journals.humankinetics.com/jsep

Williamson, J. W., McColl, R., Mathews, D., Mitchell, J. H., Raven, P. B., & Morgan, W. P. (2001). Hypnotic manipulation of effort sense during dynamic exercise: cardiovascular responses and brain activation. *Journal of Applied Physiology*, *90*, 1392–1399. doi:http://jap.physiology.org/

Wilmore, J. H. (1968). Influence of motivation on physical work capacity and performance. *Journal of Applied Physiology*, *24*, 459–463. Retrieved from http://jap.physiology.org/

Wilmore, J. H., Costill, D. L., & Kenney, W. L. (2008). *Physiology of sport and exercise* (4th ed.). Champaign, IL: Human Kinetics.

Wilson, K., & Brookfield, D. (2009). Effect of goal setting on motivation and adherence in a six-week exercise program. *International Journal of Sport and Exercise Psychology*, *7*, 89–100. doi:10.1080/1612197X.2009.9671894

Winchester, R., Turner, L. A., Thomas, K., Ansley, L., Thompson, K. G., Micklewright, D., & St Clair Gibson, A. (2012). Observer effects on the rating of perceived exertion and affect during exercise in recreationally active males. *Perceptual and Motor Skills*, *115*, 213–227. doi:10.2466/25.07.05.PMS.115.4.213-227

Wittekind, A. L., Micklewright, D., & Beneke, R. (2011). Teleoanticipation in all-out short-duration cycling. *British Journal of Sports Medicine*, *45*, 114–119. doi:10.1136/bjsm.2009.061580

Wolf, M. M. (1978). Social validity: The case for subjective measurement or how applied behavior analysis is finding its heart. *Journal of Applied Behavior Analysis*, *11*, 203–214. doi:10.1901/jaba.1978.11-203

Wollmer, M. A., Boer, C. De, Kalak, N., Beck, J., Götz, T., Schmidt, T., … Kruger, T. H. C. (2012). Facing depression with botulinum toxin: A randomized controlled trial. *Journal of Psychiatric Research, 46,* 574–581. doi:10.1016/j.jpsychires.2012.01.027

Wright, R. A. (2008). Refining the prediction of effort: Brehm's distinction between potential motivation and motivation intensity. *Social and Personality Psychology Compass*, *2*, 682–701. doi:10.1111/j.1751-9004.2008.00093.x

Wrisberg, C. A., Franks, B. D., Birdwell, M. W., & High, D. M. (1988). Physiological and psychological responses to exercise with an induced attentional focus. *Perceptual and Motor Skills, 66,* 603–616. doi:10.2466/pms.1988.66.2.603

Zinsser, N., Bunker, L., & Williams, J. M. (2001). Cognitive techniques for building confidence and enhancing performance. In J. M. Williams (Ed.), *Applied sport psychology: Personal growth to peak performance* (4th ed., pp. 284–311). Mountain View, CA: Mayfield.

Chapter 8

Appendices

Appendix A

Keywords Included in Database Searches (Chapter 2)

Words meaning "endurance" and direct measures of endurance performance (*n* = 33)

Endurance OR ultra-endurance OR "exercise tolerance" OR "exercise resilience" OR "work capacit*" OR "time-to-exhaustion" OR "time to exhaustion" OR "time to fatigue" OR "time-to-fatigue" OR "time trial*" OR "time-trial*" OR "performance time*" OR "performance distance*" OR "total power" OR "power output" OR "peak power" OR "maximum power" OR "maximal power" OR "exercise performance" OR "exercise time" OR "exercising time" OR "treadmill time" OR "distance ran" OR "distance cycled" OR "distance swam" OR "distance rowed" OR "volitional exhaustion" OR "voluntary exhaustion" OR "physical performance" OR "peak velocit*" OR "peak treadmill velocit*" OR "peak speed" OR "peak treadmill speed"

Physiological dependent variables measured during endurance performance (*n* = 16)

Economy OR efficiency OR "VO2" OR "V O2" OR "VO 2" OR "VO2max" OR "[Vdot]O2" OR "[Vdot] O2" OR "VO2peak" OR "maximal aerobic" OR "maximum aerobic" OR "maximal oxygen" OR "maximum oxygen" OR "peak oxygen" OR pacing OR pace

Running keywords (*n* = 21)

Run OR runner OR runners OR running OR cross-country OR "cross country" OR "fitness test" OR "beep test" OR "beep-test" OR "bleep test" OR "bleep-test" OR "pacer test" OR "pacer-test" OR "Leger test" OR "Leger-test" OR "shuttle run" OR "shuttle-run" OR marathon OR marathoner OR ultra-marathon OR ultra-marathoner

Cycling keywords (*n* = 8)

Cycle OR cyclist OR cyclists OR cycling OR bicycle OR ergometer OR bike OR biking

Swimming keywords (*n* = 4)

Swim OR swimmer OR swimmers OR swimming

Rowing keywords (*n* = 4)

Row OR rower OR rowers OR rowing

Skiing keywords (*n* = 4)

Ski OR skiing OR skier OR skiers

Canoeing keywords (*n* = 4)

Canoe OR canoer OR canoers OR canoeing

Kayaking keywords (*n* = 4)

Kayak OR kayaker OR kayakers OR kayaking

Multi-leg sport keywords (*n* = 10)

Triathlon OR triathlete OR triathletes OR biathlon OR biathlete OR biathletes OR duathlon OR duathlete OR duathletes OR Ironman

Speedskating keywords (*n* = 8)

Speedskate OR speedskater OR speedskaters OR speedskating OR "speed skate" OR "speed skater" OR "speed skaters" OR "speed skating"

Race walking keywords (*n* = 12)

Walk OR racewalk OR "race-walk" OR walking OR racewalking OR "race-walking" OR walker OR racewalker OR "race-walker" OR walkers OR racewalkers OR "race-walkers"

Keywords relating to psychological interventions (*n* = 78)

psychologic* OR mental* OR cognitive* OR psychobiological* OR psychosocial* OR psychophysiolog* OR MST OR PST OR "performance enhancement" OR "performance-enhancement" OR strateg* OR technique* OR effective* OR "self-talk" OR "self talk" OR imagery OR visualisation OR visualization OR PETTLEP OR relaxation OR goal* OR "approach-goal*" OR "avoidance-goal*" OR "achievement-goal*" OR state OR optimism OR efficacy OR "self-efficacy" OR confidence OR self-confidence OR self-doubt OR doubt* OR motivation OR "self-determination" OR reward OR incentive* OR reinforcement OR encouragement OR compet* OR coaction OR "social facilitation" OR attention* OR focus OR concentration OR fear OR anxiety OR nervous* OR nerves OR arousal OR stress OR distress OR pressure OR mood OR affect OR emotion OR coping OR hypnosis OR hypnotic OR "post-hypnotic" OR "post hypnotic" OR RPE OR effort OR exertion OR fatigue OR belief OR "self-belief" OR feeling* OR association OR dissociation OR associative OR dissociative OR mindful* OR acceptance OR meditation OR meditating OR biofeedback OR bio-feedback OR talking

Appendix B

Study Quality Evaluation Application Script
(Modified From B. H. Thomas, Ciliska, Dobbins, & Micucci, 2004) (Chapter 2)

Studies were evaluated against their own research aims. “Not applicable” was assigned when an evaluation criterion was judged to not be relevant to the aims of a study. Judgments were made when the “correct” rating was unclear.

Selection Bias

The Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (QATQS) Dictionary explains that participants are very likely to be representative of a target population if they are randomly selected from a comprehensive list of individuals in that target population (“strong” rating). Participants are somewhat likely to be representative of a population (“moderate” rating) if they are systematically referred from a source (e.g., clinic, coach). Participants are unlikely to be representative if they are self-referred (“weak” rating).

Study Design

The QATQS Dictionary explains that, “In stronger designs, an equivalent control group is present and the allocation process is such that the investigators are unable to predict the sequence” and that, in an experimental study, “raters assess the likelihood of bias due to the allocation process”.

Strong ratings:

- Between-subjects and pretest-posttest group designs that included control groups and randomly allocated participants to groups (with or without matching procedures).
- Within-subject designs where the order of experimental and control conditions was completely randomised (or randomised and counterbalanced).

Moderate ratings:

- Between-subjects and pretest-posttest group designs that included control groups but did not state using randomisation.
- Within-subject group designs with counterbalancing but not stating randomisation.
- Quasi-experimental group designs (e.g., randomisation of pre-existing groups, allocation by participant characteristics).
- Pretest-posttest group designs with multiple pretests and no control group.

Weak ratings:

- Single-subject, multiple-baseline designs.
- Pretest-posttest group designs without a control group and only one pretest.

- Studies where the design could not be determined. In contrast to the QATQS, attempts were made to determine the research design if it was not explicitly stated (rather than assigning "weak").

Confounders

The QATQS Dictionary defines a confounder as, "a variable that is associated with the intervention or exposure and causally related to the outcome of interest". In line with the QATQS Dictionary, attempts were made to determine whether groups were balanced with respect to important variables prior to the intervention, and if attempts were made to control confounding variables in the design (e.g., through matching procedures) or analysis (e.g., through appropriate use of statistics). When designs included more than one experimental group or a control group, the pre-intervention performances of the groups were compared. Other variables that may also affect performance (e.g., age, gender, competitive level, presence of competition) were also compared. An attempt was made to identify potential confounders throughout the description of the research method. The reviewer considered whether there were any differences (e.g., environmental, procedural) between experimental and control conditions, other than the intervention itself. Within-subject designs were often rated as "strong", because participants acted as their own control in consistent environments. In contrast to the QATQS, "weak" was not assigned if the control of confounders was not described, because it is not typical practice to report this information in sport science research.

Blinding

Judgments were made regarding whether the expectations of the researcher or the participants could have affected the outcome measure. First, a judgment was made regarding whether researchers who were present at post-intervention testing were blinded to the intervention-status of participants (i.e., whether participants were in an experimental or control condition) or the research aims or hypotheses. The reviewer looked for reference to a blinded research assistant. Second, a judgment was made regarding whether the participants were aware of the research question. The reviewer considered whether studies used deception or concealment of information and whether they informed participants of the likely effects of the intervention on performance. The reviewer also considered whether the research question was likely to be obvious to participants (e.g., the effect of an obvious intervention on performance). As few articles explicitly described blinding, a judgment was made using the information available in the article. "Strong" was assigned when both the researcher and the participant were blinded. "Moderate" was assigned when either the researcher or the participant were blinded, or when blinding was unclear in both instances. "Weak" was assigned when neither the researcher nor the participant appeared to be blinded.

Data Collection Methods

The QATQS Dictionary explains that, “Tools for primary outcome measures must be described as reliable and valid” and that, “Reliability and validity can be reported in the study or in a separate study”. The QATQS recognises that some standard assessment tools have known reliability and validity. In most cases, the primary data collection tool was a measure of endurance performance. Only studies that were judged to have used a valid measure of endurance performance were included in the systematic review and so, for consistency, all studies that used an endurance-performance measure as the primary dependent variable were judged to have used a valid outcome measure. For those studies that used running economy or $\dot{V}O_{2max}$ as the primary dependent variable, measurement procedures with known validity were considered acceptable. For an outcome measure to be considered reliable, the study was required to quote reliability data, reliability criteria, or a reference supporting reliability.

Withdrawals and Dropouts

Reporting withdrawals and dropouts was considered to be relevant for those practical psychological intervention studies that looked at the effect of training in a performance-enhancement intervention on endurance performance (i.e., where there was a considerable investment of time and effort to the intervention) and practical psychological intervention studies that included more than one posttest / performance in an experimental condition. Participants who dropped out may have been less likely to show a beneficial response to the intervention, and excluding these participants from the analysis could lead to biased conclusions.

Intervention Integrity

The reviewer noted whether the consistency of the intervention was measured or whether the intervention was delivered using a standardised procedure (i.e., whether the intervention was provided to all participants in the same way). Additionally, the reviewer noted whether participants were likely to have received an unintended intervention (contamination or co-intervention) that could have influenced the results. Specifically, the reviewer considered whether the experimental group could have received an additional intervention (co-intervention) or whether the control group could have accidentally received the experimental intervention (contamination). For example, to prevent contamination, some studies reported asking participants to not discuss the intervention with other participants.

Analyses

None of the studies reported using an intention-to-treat analysis. The reviewer noted the analysis conducted on performance data, as well as whether the authors justified the choice of statistical analysis.

Appendix C

Example Audit Trail for the Evaluation of Study Quality (Chapter 2)

Barwood, Thelwell, and Tipton (2008)

Selection Bias / Sample

- "Weak" assigned. Participants were volunteers. Participants were not endurance athletes (p. 388, "Methods" section, paragraph 1).

Study Design

- "Strong" assigned. Pretest-posttest design with a control group. Participants were matched then randomly assigned to groups (p. 388, "Methods" section, paragraph 2).

Confounders

- "Strong" assigned.
- Participants were randomly assigned to groups. Participants were matched by the difference in performance between runs 1 and 2. Matched pairs had run within 270 metres of each other (p. 388, "Methods" section, paragraph 2).
- The participant characteristics appear homogeneous (all males of similar age, height, weight, and body fat). $\dot{V}O_{2max}$ was not significantly different between groups ($p > .05$, p. 391, "Results" section, paragraph 1).
- Confounders were not identified in the description of the research method.

Blinding

- "Moderate" assigned.
- Q1 – 3. "Can't tell". The report does not refer to a research assistant who was blinded to the research aims, hypotheses, or condition allocation.

- Q2 – 2. “No”. The control group were not aware of the content of the psychological skills training intervention or its delivery (p. 389, “Main Study” section, paragraph 12). This suggests that participants were unaware of the aims and hypotheses until after trial 2 (experimental group) or trial 3 (control group).

Data Collection Methods

- “Moderate” assigned.
- Q1 – 1. “Yes”. The endurance performance measure meets the inclusion criteria for an endurance performance dependent variable. The validity of this performance measure was not referred to in the article.
- Q2 – 2. “No”. The reliability of the endurance performance measure was not referred to in the article.

Withdrawals and Drop-outs

- “Weak” assigned.
- Q1 – 2. “No”. Not reported. There was one post-intervention performance. The training commitment was four hours over four days (p. 388, “Main Study” section, paragraph 5).

Intervention Integrity

- The consistency of the intervention was not measured. The content of the intervention is described in detail (pp. 388-389, “Main Study” section), and the intervention was overseen by an accredited sport psychologist (p. 389, “Positive self-talk” section).
- No co-intervention or contamination. Control participants were not aware of the content of the intervention or its delivery to the experimental group (p. 389, “Main Study” section, paragraph 12).

Analyses

- Repeated measures ANOVAs within each group (p. 390, "Statistical Analyses" section). No supporting reference. Pretest-posttest design.

Use of Intervention

- Somewhat. Participants in the experimental group completed a psychological skills use questionnaire to assess their reactions to the psychological skills training and the performance outcomes. This measure does not appear to check if, or how frequently, participants used the intervention. After the third performance, the comments of the participants in both groups regarding their use of any psychological skills were noted (p. 390, "Measurements" section, paragraph 4, see also Table 5 of manuscript, p. 394).

Placebo Condition / Group

- No placebo control group.

Psychological Mediating Variables

- Ratings of perceived exertion were collected (p. 390, "Measurements" section, paragraph 3).

Social Validity

- Somewhat. After the third performance, participants completed a psychological skills use questionnaire to assess their reactions to the psychological skills training and the performance outcomes. The rating of the usefulness of each psychological skill before and during the third performance is presented in Table 5 of the manuscript (p. 394).

Individual Responses to Intervention

- Not reported.

Moderating Variables

- Moderating variables were not considered.

Justification of Intervention

- The intervention was designed to meet the demands of exercising in the heat. Research was cited that demonstrates the efficacy of psychological skills training at enhancing endurance performance and breath-hold performance during cold water immersion (see Introduction section of manuscript).

Appendix D

Reasons for Study Exclusion (Chapter 2)

Table A1

Reasons for Study Exclusion

Study	Abstract details	Manuscript details	Reason for exclusion
Andreacci et al. (2002)	Appears relevant.	The exercise test ended when the participant either attained $\dot{V}O_{2max}$ or reached exhaustion (p. 347).	Dependent variable does not meet inclusion criteria
Andreacci et al. (2004)	Does not appear relevant from the abstract (no reference to performance time). The manuscript was studied, however, because endurance time was likely to have been measured.	The criteria for terminating the exercise test were unclear, so I contacted the author. The author stated, "Exercise time was the total time that a person spent on the treadmill and ended when they terminated the test or met $\dot{V}O_{2max}$ criteria."	Dependent variable does not meet inclusion criteria
Anshel (1995)	Appears relevant. Two endurance durations.	Performance was not measured in consistent experimental conditions (individual performance versus simulation of a rowing team).	Performance was not measured in consistent experimental conditions.
Baghurst, Thierry, & Holder (2004)	Appears relevant.	No control group.	No control condition.
Bandura & Cervone (1983)	Relevance unclear.	The "stenuous activity" (pulling and pushing two arm levers) does not meet the endurance definition of the review.	Dependent variable does not meet inclusion criteria
Bar-Eli & Blumenstein (2004a)	Relevance unclear.	Swimming and running distances do not meet the inclusion criteria (all < 35 s).	Dependent variable does not meet inclusion criteria
Bar-Eli & Blumenstein (2004b)	Relevance unclear.	Performance distances (30 m) do not meet the inclusion criteria.	Dependent variable does not meet inclusion criteria
Bar-Eli, Dreshman, Blumenstein, & Weinstein (2002)	Relevance unclear.	Performance times do not meet the inclusion criteria (all < 40 s).	Dependent variable does not meet inclusion criteria

(continued)

Table A1 (*continued*)

Study	Abstract details	Manuscript details	Reason for exclusion
Barling & Bresgi (1982)	Unlikely to meet inclusion criteria.	Performance times are less than 75 s.	Dependent variable does not meet inclusion criteria
Beauchamp, Harvey, & Beauchamp (2012)	Unlikely to be an appropriate design or measure performance objectively.	Not an experiment.	Design does not meet the inclusion criteria.
Bueno, Weinberg, Fernández-Castro, & Capdevila (2008)	Did not appear to meet inclusion criteria.	Confirmation that study does not meet inclusion criteria. This is a mechanism study rather than an applied intervention study.	Design does not meet the inclusion criteria.
Burton (1989)	Relevance unclear.	Endurance and non-endurance distances but results not presented separately.	Dependent variable does not meet inclusion criteria.
Callow, Roberts, & Fawkes, (2006)	Appears relevant, depending on the performance distance.	Performance times < 40 s	Dependent variable does not meet inclusion criteria.
Callow, Roberts, Hardy, Jiang, & Edwards (2013)	Experiments 2 and 3 appear relevant, depending on the performance distances.	Experiment 2 – Performance times < 20 s Experiment 3 – Performance times < 25 s	Dependent variable does not meet inclusion criteria.
Carnes, Barkley, Williamson, & Sanders (2013)	Appears relevant, and distance covered is measured.	"This is not a test to see how fast or far you can go." (p. 2)	Not full-effort performance.
Clingman & Hilliard (1990)	Relevance unclear.	Race-walking performance but not race-walking performance distance (only 0.5 miles, as stated in the abstract)	Dependent variable does not meet inclusion criteria.
Connolly & Janelle (2003)	Appears relevant. Unclear if there is a control group in Experiment 1.	Experiment 1 – Association and dissociation but no control. Also not full-effort performance. Experiment 2 – Control group but not full-effort performance.	Not full-effort performance.
Couture et al. (1999)	Appears relevant.	Participants swam as fast as comfortably possible. Therefore not full-effort performance.	Not full-effort performance.
De Petrillo, Kaufman, Glass, & Arnkoff (2009)	Appears relevant.	Running performance was not objectively measured.	Dependent variable does not meet inclusion criteria.

(continued)

Table A1 (*continued*)

Study	Abstract details	Manuscript details	Reason for exclusion
Díaz-Ocejo, Kuitunnen, & Mora-Mérida (2013)	Relevance unclear. Not likely to meet experimental design inclusion criteria.	Case study. Not an experiment or quasi-experiment.	Design does not meet the inclusion criteria.
Everett, Smith, & Williams (1992)	Performance distance / duration not stated.	Performance times are below 75 s.	Dependent variable does not meet inclusion criteria
Fillingim & Fine (1986)	Effect of attentional focus on performance. Appears relevant.	Participants were told to “jog as fast as you can without experiencing any discomfort” (p. 117). Therefore not full-effort performance.	Not full-effort performance.
Fillingim, Roth, & Haley (1989)	Appears relevant.	Not full effort performance.	Not full-effort performance.
Goudas, Theodorakis, & Laparidis (2007)	Appears relevant as measures the effect of goal setting on endurance performance.	Performance was measured by the time point at which the participant reached 170 beats per minute.	Dependent variable does not meet inclusion criteria.
Gould, Tuffey, Hardy, & Lochbaum (1993)	Abstract not found.	Correlational	Design does not meet the inclusion criteria.
Gravel, Lemieux, & Ladouceur (1980)	Appears relevant.	Performance was not objectively measured and then presented.	Dependent variable does not meet inclusion criteria.
Greenlees, Graydon, & Maynard (1999)	Appears relevant.	700 m cycling performance < 75 s	Dependent variable does not meet inclusion criteria.
Gregg, Hrycaiko, Mactavish, & Martin (2004)	Relevance unclear.	The multiple-baseline design did not apply to the performance variable.	Design does not meet the inclusion criteria.
Hall & Byrne (1988)	“Endurance task”	Sit up endurance	Dependent variable does not meet inclusion criteria.
Hanton & Jones (1999)	Appears relevant.	Performance times are below 75 s.	Dependent variable does not meet inclusion criteria.
Hatzigeorgiadis, Galanis, Zourbanos, & Theodorakis (2014)	Appears relevant. Competitive distance not reported.	Endurance and non-endurance distances but results not presented separately.	Dependent variable does not meet inclusion criteria.
Kavanagh & Hausfeld (1986)	Relevance unclear as task not specified	Muscular endurance	Dependent variable does not meet inclusion criteria.

(continued)

Table A1 (*continued*)

Study	Abstract details	Manuscript details	Reason for exclusion
Kleine, Sampedro, & Melo (1988)	Appears relevant.	Experiment 1 – The dependent variable is not a measure of endurance. Experiment 2 – Performance distance from 100 m to 10,000 m presented together.	Dependent variable does not meet inclusion criteria.
LaCaille, Masters, & Heath (2004)	Performance time was a dependent variable. Cognitive strategy was an independent variable. Unclear if there is a control group.	No control condition. Also, it is unclear if participants were required to offer full effort.	No control condition.
Padgett & Hill (1989)	Performance time was a dependent variable in Experiment 2. Unclear what "normal training pace" means. Exercise setting was used to manipulate attentional focus so could be relevant.	Still unclear. Email correspondence with the author suggested that it was not full-effort performance.	Not full-effort performance.
Pavlidou & Doganis (2008)	Appears relevant.	50 m performance.	Dependent variable does not meet inclusion criteria.
Pennebaker & Lightner (1980)	The abstract provided insufficient information to make a judgment about Experiment 2.	Participants were "instructed that they should jog at whatever pace was comfortable to them, that speed was not an object in the experiment, and that they could walk rather than jog if they so desired" (p. 170)	Not full-effort performance.
Perreault, Vallerand, Montgomery, & Provencher (1998)	Appears relevant.	Measured changes in % peak power across four stages of performance. Values are reported for 11 of 12 performance minutes.	Dependent variable does not meet inclusion criteria.
Rushall, Hall, Roux, Sasseville, & Rushall (1988)	Appears relevant.	Not considered cross-country skiing performance. The duration of each effort took from 70 to 130 s.	Dependent variable does not meet inclusion criteria.
Schomer (1987)	Unlikely to be relevant. This paper is frequently cited, however, and there have been suggestions in the literature that the intervention enhanced performance.	Performance was not formally / objectively measured.	Dependent variable does not meet inclusion criteria.
Schüler & Langens (2007)	Study 2 appears relevant.	Hierarchical analysis of regression	Design does not meet the inclusion criteria.

(continued)

Table A1 (*continued*)

Study	Abstract details	Manuscript details	Reason for exclusion
Sewell (1996)	Appears relevant.	Participants performed at 75% of race pace.	Not full-effort performance.
Smith, Hauenstein, & Buchanan (1996)	Relevance unclear.	Sit up endurance	Dependent variable does not meet inclusion criteria.
Sorrentino & Sheppard (1978)	Appears relevant. The performance duration is likely > than 75 s.	Performance was not measured in consistent experimental conditions (representing theirself versus representing their group).	Performance was not measured in consistent experimental conditions.
Spink & Longhurst (1986)	Appears relevant.	"The original group assignments were disregarded and subjects were regrouped according to the actual cognitive strategy employed" (p. 11)	Study design does not meet the inclusion criteria.
Theodorakis (1995)	Appears relevant.	Performance time = 20 s	Dependent variable does not meet inclusion criteria.
Thompson, Kaufman, De Petrillo, Glass, & Arnkoff (2011)	Unlikely to meet inclusion criteria because it is a follow-up of an earlier study (De Petrillo et al. (De Petrillo et al., 2009)) that did not meet the inclusion criteria.	Not an experiment and performance was not measured objectively.	Design does not meet the inclusion criteria.
Wanlin, Hrycaiko, Martin, & Mahon (1997)	Appears relevant.	Performance times were below 75 s.	Dependent variable does not meet inclusion criteria.
Weinberg, Bruya, & Jackson, (1990)	This is a reaction to Hall and Byrne (Hall & Byrne, 1988), which was not included. No reference to type of task.	Sit up endurance.	Dependent variable does not meet inclusion criteria.
Weinberg, Gould, & Jackson, (1980)	No abstract. "Motor tasks"	Not endurance.	Dependent variable does not meet inclusion criteria.
K. D. Williams, Nida, Baca, & Latané (1989)	Performance distance / duration not stated.	Performance times are below 75 s.	Dependent variable does not meet inclusion criteria.
Wrisberg, Franks, Birdwell, & High (1988)	Appears relevant. Unclear if there is a control group.	No control condition. Participants were also described as "normally inactive" in the Introduction.	No control condition.

Appendix E

Descriptive Overview of Included Studies (Chapter 2)

Table A2

Descriptive Overview of Practical Intervention Studies

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Association and dissociation	Morgan, Horstman, Cymerman, & Stokes (1983)	27 males serving in the army (age = 22.3 ± 0.4).	Pretest-posttest design with a randomised control group (pre = 1 post = 1).	Walking Exercise time in an incremental test.	Dissociative cognitive strategy (D). Ps were instructed to concentrate on and chase a spot in front of them and to repeat the word “down” with each leg movement.	Endurance time was greater in the D group (M = 21.5 min) than the control (M = 14.5 min). More Ps improved in the D group ($p < .02$). Δ = 1.06.
	Okwumabua, Meyers, Schleser, and Cooke (1983	31 university students from running fitness classes (f = 20, m =11, M age = 21.4).	Pretest-posttest design with two experimental groups and a control. Classes were randomly assigned as a group (pre = 1, post = 2).	Running Performance time in a 1.5-mile run on a track.	Association (A) or dissociation (D). A = monitoring bodily signals. D = focusing on task-irrelevant objects and repeating a rhythmic phrase. Verbal instructions were given on a group basis. The first set of instructions lasted ten minutes, and they were paraphrased during two additional weekly sessions.	All groups improved ($p < .01$) from the second to third performance (A = 9.5% / 1.32 min, D = 5.8%, placebo = 5.4%). A significant difference was not found between conditions. A Δ = 0.46. D Δ = 0.88.
	Saintsing, Richman, and Bergey (1988)	50 university students (f = 19, m = 31).	Pretest-posttest design with three experimental groups and a control. Ps were matched before assignment (pre = 2, post = 2).	Running Performance time in a 1.5-mile run on a track.	Association (A), dissociation (D), or psyching up (PU). A = task-specific thoughts including technique. D = task-irrelevant thoughts and repeating the word “down” with each stride. PU = self-chosen “firing up” method. Ps were given instructions as a group, and Ps had five minutes to mentally prepare before each run. A and D were practised during training runs.	The A group improved (M = 58.3 s) to a greater extent ($p < .05$) than those in the D (M = 39.5 s), PU (M = 37.9 s), or control groups (M = 26.8 s).

(continued)

Table A2 (*continued*)

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Association and dissociation (continued)	L. M. Scott, Scott, Bedic, & Dowd (1999)	9 rowers from a university rowing club (f = 5, m = 4, age = 20.2 ± 1.9).	Single-subject, multiple-baseline design across participants. Ps were randomly assigned one of three interventions. Ps performed 10 trials.	Rowing Distance rowed in 40 minutes on an ergometer.	Association or dissociation. Ps listened to an audio tape of a coxswain (association, A), watched a videotape of rowing races (dissociation, DV), or listened to pop music (dissociation, DM) during performance.	The A group demonstrated the greatest improvement in performance (M = 3.8% / 336 m). The DV (M = 1.3%) and DM (0.8%) groups also improved. A Δ = 6.58, PND = 100%. DV Δ = 1.63, PND = 92%. DM Δ = 0.57, PND = 30%.
	Weinberg, Smith, Jackson, & Gould (1984) Study 1	60 males from university conditioning classes.	Between-subjects design. Ps were matched and assigned to one of three experimental conditions or a control.	Running Distance ran in 30 minutes on a track.	Association (A), dissociation (D), or positive self-talk (S) during performance. A = monitoring bodily signals. D = pleasant, task-irrelevant thoughts. P = self-encouragement. Ps were given strategy instructions immediately before performing.	There was not a significant difference in the distance ran by Ps in the A, D, S, or control conditions.
Goal setting	Tenenbaum, Spence, & Christensen (1999)	28 female, secondary-school, cross-country runners (age = 14.6 ± 1.2).	Pretest-posttest design with three experimental groups and no control. Ps were assigned by block randomisation (pre = 1, post = 4).	Running Performance time in a 2.3 km run on a road course.	Assignment of an easy, challenging, or unrealistic combination of short-term and long-term goals (5%, 10%, or 15% improvement in four weeks with weekly targets). Goals were private and assigned verbally on an individual basis.	Each group's best post-intervention performance was faster (p < .02) than baseline (M = 7.8%). Improvements did not significantly differ between groups. Combined Δ (final performance) = 0.36.

(continued)

Table A2 (*continued*)

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Goal setting (continued)	Theodorakis, Laparidis, Kioumourtzoglou, and Goudas (1998)	40 university students (f = 23, m = 17, age = 20.3 ± 2.1).	Pretest-posttest design with a control group (pre = 1, post = 1).	Cycling Exercise time in an incremental test on an ergometer.	Goal setting and performance feedback. Ps set a specific goal (orally and in writing) for improved performance. Elapsed time was displayed during performance.	The goal setting group showed a greater increase ($p < .05$) in endurance performance (M = 12.3% / 110.4 s) compared to the control (M = 1.9%). Δ = 0.33.
Hypnosis	Jackson, Gass, & Camp (1979)	55 male university students (M age = 23.3).	Pretest-posttest design. Ps were assigned to one of four experimental groups or a control (pre = 1, post = 1).	Running Exercise time in an incremental test on a treadmill.	Post-hypnotic suggestion (PS). Ps were hypnotised and they then listened to a motivational passage. Interventions were delivered before performance by tape.	PS increased endurance time ($p < .02$) for high-susceptibility Ps (M = 15.9% / 57 s). The passage also increased endurance time in non-hypnotised Ps (M = 8.3%). These improvements did not significantly differ ($p > .02$). High-susceptibility PS Δ = 0.80. Low-susceptibility PS Δ = 0.13.
	Lindsay, Maynard, & Thomas (2005)	3 nationally-ranked, competitive cyclists (f = 1, m = 2, age = 25.3 ± 5.9).	Nonconcurrent single-subject, multiple-baseline design across participants. Ps raced 10 or 12 times.	Cycling Points won in competitive road races.	Hypnosis was used to condition natural triggers experienced during races (e.g., feel of handlebars) to emotions associated with optimal performance. A four-stage intervention was delivered during one session. Ps practised daily using an audiotape of the session.	The number of points gained per race clearly increased for P1, sporadically increased for P2, and decreased for P3. Δ = 1.85. PND = 52%.

(continued)

Table A2 (*continued*)

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Imagery	Burhans, Richman, & Bergey (1988)	65 university students (f = 29, m = 36, age range = 17-22).	Pretest-posttest design with three experimental groups and a control. Ps were matched before random assignment (pre = 1, post = 2).	Running Performance time in a 1.5-mile run on a track.	Pre-performance imagery of perfect skill execution, successful performance outcomes, or both. Imagery was from an external perspective. Instructions were given on a group basis. Ps practised imagery for five to ten minutes before training runs and timed runs.	Experimental and control group performances were not significantly different (p > .05) in the second of two posttests.
	Post, Muncie, & Simpson (2012)	4 competitive youth swimmers (f = 3, m = 1, age = 15.5 ± 1.3).	Single-subject, multiple-baseline design across participants. Ps performed 12 trials.	Swimming Performance time in a 1,000-yard practice set.	Individualised imagery training and development of a personal imagery script. The intervention was delivered over nine sessions across three weeks. Ps were instructed to listen to the script three times a week, including once before timed performances.	The three Ps who adhered to the intervention's protocol demonstrated improved performance (M for these three Ps = 3.0% / 22.3 s). Δ (all Ps) = 3.32. PND (all Ps) = 75%.
Pre-performance statements	Donohue, Barnhart, Covassin, Carpin, & Korb (2001)	6 female, collegiate, cross-country runners (age range = 18-21).	Within-subject design. A baseline performance preceded three counterbalanced experimental conditions.	Running Performance time in a 1 km outdoor run.	Instructional statements, motivational statements, or answering two questions (what were they thinking and feeling) during the warm-up. Ps selected the statements. Interventions were delivered by a research assistant.	Each intervention improved performance by 12 s to 19 s (6-9%). Baseline and post-intervention performances did not significantly differ (p > .05). Instructional Δ = 2.11. Motivational Δ = 1.89. Questions Δ = 1.33.

(continued)

Table A2 (*continued*)

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Pre-performance statements (continued)	Donohue et al. (2006)	90 high-school distance runners (f = 41, m = 49, age = 15.7 ± 1.1).	Pretest-posttest design with two experimental groups and a control. Ps were matched before random assignment (pre = 1, post = 1).	Running Performance time in a 1-mile run on a track.	Pre-performance motivational group intervention. Ps shouted a chosen motivational statement during group exercises. The intervention lasted 20 minutes.	Ps in the motivational intervention showed greater improvement ($p < .001$) in performance (M = 1.4% / 5 s) compared to those in yoga (M = 1 s) and control conditions (M = -1 s). Δ = 0.10.
	A. Miller & Donohue (2003)	90 high-school distance runners (f = 45, m = 45, age = 16.2 ± 1.1).	Pretest-posttest design with two experimental groups and a control. Ps were matched before random assignment (pre = 1, post = 1).	Running Performance time in a 1.6 km run on a track.	Motivational and instructional statements delivered through headphones during the three minutes preceding performance. Ps selected the statements.	Motivational and instructional statements (M = 2.3% / 8 s) and a self-selected song (M = 1.3%) improved endurance performance ($p < .001$). Statements Δ = 0.09.
	Weinberg, Miller, & Horn (2012)	81 collegiate, cross-country runners (f = 40, m = 41, age = 19.5 ± 1.3).	Pretest-posttest design with six experimental groups and no control. Ps were assigned using matching procedures (pre = 1, post = 1).	Running Performance time in a 1-mile run.	Motivational statements, instructional statements, or both (MI) were self-chosen or assigned. Ps listened to statements (read by the experimenter) on a CD for three minutes before performing. Ps believed that their coach chose the assigned statements.	Three groups improved their performance ($p < .01$). MI self-chosen statements led to the greatest improvement (M = 3.0% / 10 s). The type of statements or who assigned them did not consistently predict performance. Δ range = 0.03 - 0.18.

(continued)

Table A2 (*continued*)

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Psychological skills training (PST) package	Barwood, Thelwell, & Tipton (2008)	18 males (PST age = 23 ± 3, control age = 28 ± 5).	Pretest-posttest design with a control group. Ps were matched before random assignment (pre = 2, post = 1).	Running Distance ran during 90 minutes in 30°C heat in a climate chamber.	PST package to meet the demands of exercising in the heat. Four one-hour PST sessions were delivered in the four days preceding performance (goal setting, arousal regulation, mental imagery, and positive self-talk).	The PST group ran farther (M = 8% / 1.15 km) after receiving the intervention ($p < .05$). The control group ran similar distances in each trial. Δ = 0.54.
	Patrick & Hrycaiko (1998)	3 triathletes of varying ability and 1 national-level runner (m = 4, age range = 25-37).	Single-subject, multiple-baseline design across participants. Ps performed 11 trials.	Running Performance time in a 1.6 km run on a track.	PST package delivered on an individual basis over three days (relaxation, imagery, self-talk, and goal setting). Skills were presented in a self-teaching workbook that contained reading and exercises. The first two sessions lasted 90 minutes, and a third session was dedicated to answering questions.	All Ps improved their performance following the intervention. Δ = 4.22. PND = 83%.
	Sheard & Golby (2006)	36 national-level swimmers (f = 23, m = 13, age = 13.9 ± 2.0, age range = 10-18).	Pretest-posttest design without a control group. Ps' best competitive performance times were obtained pre-, post-, and one-month post-intervention.	Swimming Competition performance times for different strokes and distances.	PST program. Five weekly sessions were conducted on a one-to-one basis (goal setting, visualisation, relaxation, concentration, and thought stopping). Each session was personalised and lasted 45 minutes.	Performance time was faster ($p < .05$) in one out of five endurance events post-intervention. Performance times were faster ($p < .05$) in two endurance events one-month post-intervention. Δ (post) = 0.03. Δ (one-month post) = 0.28.

(continued)

Table A2 (*continued*)

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
PST package (continued)	Thelwell & Greenlees (2001)	5 male members of a gymnasium (age = 24.2 ± 4.6).	Single-subject, multiple-baseline design across participants. Ps performed 10 trials.	Gymnasium triathlon (2 km row, 5 km cycle, 3 km run) Performance time.	PST package delivered on a one-to-one basis over four consecutive days (goal setting, relaxation, imagery, and self-talk). Each session lasted up to one hour and included education, workbook exercises, and homework.	All Ps improved their performance (M = 32.6 s) following the intervention. Δ = 2.80. PND = 81%.
	Thelwell & Greenlees (2003)	4 male members of a gymnasium (age range = 19-21).	Single-subject, multiple-baseline design across participants. Ps performed 10 trials.	Gymnasium triathlon Performance time.	See Thelwell and Greenlees (2001).	All Ps improved their performance (M = 7.5% / 81 s) following the intervention. Δ = 4.29. PND = 90%.
Relaxation and biofeedback	Caird, McKenzie, & Sleivert (1999)	7 sub-elite, competitive, long-distance runners.	Within-subject design (pre = 2, post = 1).	Running Peak velocity in a treadmill incremental test.	Biofeedback, progressive muscular relaxation, and centering to improve running economy. Ps attended training three times each week for six weeks (13-25 minutes per visit). Ps also practised lowering their heart rate each day using centering.	Biofeedback and relaxation improved running economy. Peak running velocity was unchanged.

(continued)

Table A2 (*continued*)

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Self-talk	Barwood, Corbett, Wagstaff, McVeigh, & Thelwell (2015)	14 recreationally-active males (age = 19 ± 1).	Pretest-posttest design with a control group. Ps were matched before assignment (pre = 3, post = 1).	Cycling Performance time in a 10 km time trial on an ergometer.	One-hour classroom session with a structured workbook. Ps identified their used negative self-talk statements and chose motivational statements to counter them with during each 2 km section. Ps rehearsed statements during the days and moments preceding each time trial.	Motivational self-talk improved time-trial performance (M = 3.75%, $p < .01$). Neutral self-talk did not (M = -1.30%, $p = .312$) Δ = 0.39.
	Blanchfield, Hardy, de Morree, Staiano, & Marcora (2014)	24 recreationally-trained individuals (f = 9, m = 15, age = 24.6 ± 7.5).	Pretest-posttest design with a randomised control group (pre = 1, post = 1).	Cycling Time to exhaustion on an ergometer.	Two-stage self-talk intervention delivered over two weeks using a workbook. Stage 1 = introduction to self-talk and selection of four motivational self-talk statements. Stage 2 = using self-talk during three or more exercise sessions.	Time to exhaustion increased ($p < .05$) in the self-talk group (M = 17.9% / 114 s) but not in the control (-2.5%). Δ = 0.66.
	Hamilton, Scott, & MacDougall (2007)	9 university students (f = 3, m = 6, age = 20.9 ± 2.9).	Single-subject, multiple-baseline design across participants. Ps were randomly assigned to one of three interventions. Ps performed 10 trials.	Cycling Total work during 20 minutes of ergometer cycling.	Self-regulated positive (SP), assisted positive (AP), or assisted negative (AN) self-talk. In the SP condition, Ps were instructed in how to use positive statements during performance. In the assisted conditions, Ps were encouraged to use statements that were delivered by audiotape.	The AP group demonstrated the greatest performance improvement (M = 32.0%). The SP (M = 23.4%) and AN (11.0%) groups also increased total work. AP Δ = 4.56. PND = 100%. SP Δ = 2.35. PND = 100%. AN Δ = 0.48. PND = 37%.

(continued)

Table A2 (*continued*)

Intervention category	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Self-talk (continued)	Rushall & Shewchuk (1989)	6 nationally-ranked swimmers (f = 4, m = 2).	Within-subject design. Experimental and control trials were included within each performance (e.g., alternation every 100 m during the 400 m swim).	Swimming Training times for two 400 m swims and a set of eight 100 m repeats.	Positive thinking (PT, e.g., "I'm doing great"), mood words (MW, e.g., "blast"), or task-relevant thinking (TT, e.g., "elbows up") during performance. Ps were given an instruction sheet with explanations and examples, and they practised during two training sessions.	For the 400 m effort swims and the eight 100 m repeats, times were faster in the PT (M = 1.4% and 2.1%), MW (M = 3.1% and 2.3%) and TT (M = 3.1% and 2.5%) conditions compared to the control ($p < .05$).

Note. f = number of female participants; m = number of male participants; M = mean; P(s) = participant(s); PND = mean percentage of non-overlapping data points; post = number of post-intervention performances; pre = number of pre-intervention performances; ± = mean ± standard deviation; Δ= effect size (Glass's delta).

Table A3

Descriptive Overview of Additional Psychological Determinant Studies

Psychological determinant	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Co-participation	Bath et al. (2012)	11 club-level male athletes (age = 33 ± 8).	Within-subject design. T2-T4 were randomised. T1 = Self-paced T2 = Running behind co-participant T3 = Running ahead of co-participant T4 = Running alongside T5 = Self-paced	Running Performance time in a 5 km time trial on a track.	A second runner who ran at a similar pace and maintained a set distance. Ps were not instructed to compete against the second runner.	Performance times were not significantly different between trials (*p* = .208). Mean Δ = - 0.07
	Williams et al. (2015)	15 competitive male cyclists (median age = 34).	Within-subject design. T3-T4 were randomised and counterbalanced. T1 = Familiarisation T2 = One avatar (P progress). T3 = Two avatars (P + competitor progress) T4 = Feedback of distance covered	Cycling Performance time in a 16.1 km time trial on an ergometer.	An avatar representing the previous performance of another cyclist of similar ability. Ps were not instructed to compete against the avatar. The competitor's avatar was actually a representation of their best performance in T1 or T2.	Ps performed faster in the co-participation trial (27.8 ± 2.0 min) than T2 (28.7 ± 1.9 min, *p* = .001) and T4 (28.4 ± 2.3 min, *p* = .067). Δ (versus T2) = 0.47. Δ (versus T4) = 0.26.
Efficacy strength (ES)	M. Miller (1993)	84 regional- or national-level swimmers (f = 42, m = 42, age = 14.4 ± 3.0, age range = 10-22).	Between-subjects design. Random assignment with matching.	Swimming Performance time in a 200 m medley.	Assignment of a goal time slower (high ES) or faster (low ES) than their personal best.	Ps with high ES performed better (relative to their personal-best times) than Ps with low ES, independent of skill level (*p* < .001).

(continued)

Table A3 (*continued*)

Psychological determinant	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Emotion suppression	Wagstaff (2014)	19 club, national, or international-level swimmers, runners, or rowers (f = 9, m = 10, age = 21.1 ± 1.6).	Within-subject design. T2-T4 were randomised and counterbalanced. T1 = Familiarisation T2 = Control T3 = Suppression T4 = Nonsuppression	Cycling Performance time in a 10 km time trial on an ergometer.	Pre-performance intervention. Ps were asked to conceal their emotions whilst watching a disgusting video.	Ps performed slower (p = .02) in the suppression condition (18.4 ± 1.1 min) than the nonsuppression (18.0 ± 1.2) and control conditions (17.8 ± 1.1 min). Δ (versus nonsuppression) = 0.34. Δ (versus control) = 0.56.
Experimenter characteristics	Bubb et al. (1985) Study 1	80 college students (f = 40, m = 40).	Between-subjects design.	Running Exercise time in an incremental test on a treadmill.	The experimenter was the same or opposite sex of the participant, and they were categorised as being the same or different race.	An interaction effect (p = .029) indicated that experimenter sex could influence endurance performance, depending on the sex and race of Ps.
	Bubb et al. (1985) Study 2	20 adults (f = 10, m = 10).	Between-subjects design.	Running Exercise time in an incremental test on a treadmill.	Participants were either friends with the researcher or they were unfamiliar with one another.	There was not a significant difference in performance between groups (p > .10).

(continued)

Table A3 (*continued*)

Psychological determinant	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Financial incentive	Hulleman, de Koning, Hettinga, & Foster (2007)	7 male cyclists who competed at regional level (age = 32.1 ± 10.8).	Within-subject design (pre = 3, post = 1).	Cycling Performance time in a 1.5 km time trial on an ergometer.	Monetary incentive ($100) to beat their best time by more than one second.	There was not a significant difference in performance time or total power output ($p > .05$) following the incentive (T2 time = 133.1 ± 2.1 s, T3 = 134.1 ± 3.4s, T4 = 133.6 ± 3.0 s).
Head-to-head competition	Corbett, Barwood, Ouzounoglou, Thelwell, & Dicks (2012)	14 male regular exercisers (age = 19 ± 1).	Within-subject design. T4 and T5 were counterbalanced. T1-3 = Familiarisation T4 = Exercising alone T5 = Simulated head-to-head competition.	Cycling Performance time in a 2 km time trial on an ergometer.	Competition against their best familiarisation trial, disguised as head-to-head competition against a competitor of similar ability.	Ps performed faster ($p = .021$) in the competitive condition (T5 = 184.6 ± 6.2 s) than when they performed alone (T4 = 188.3 ± 9.5 s). $\Delta = 0.39$.
	Higgs (1972)	20 female university students.	Pretest-posttest design without a control group (pre = 1, post = 1).	Running Time to exhaustion on a treadmill.	Head-to-head competition against a “matched” competitor (the competitor had superior endurance).	Ps ran for longer ($p < .01$) in the competitive condition (M = 299.4 s) than the self-motivated condition (M = 270.9 s), independent of their level of competitiveness.

(continued)

Table A3 (*continued*)

Psychological determinant	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Head-to-head competition (continued)	Peveler & Green (2010)	8 recreational or trained male cyclists (age = 39 ± 7).	Within-subject design. T3 and T4 were counterbalanced. T1 = Familiarisation T2 = Improve ranked position T3/T4 = Competition (chasing or leading).	Cycling Performance time in a 20 km time trial on an ergometer.	Head-to-head competition against their closest competitor in a chasing or leading position.	Performance times were not significantly different ($p > .05$) when Ps were trying to improve their ranked position (33.8 ± 1.4 min), chasing (33.5 ± 1.3 min), and leading (33.8 ± 1.6 min). Chasing (compared to T2) $\Delta = 0.23$. Leading $\Delta = 0.03$.
	Wilmore (1968)	22 male university students (age = 22.3 ± 3.54).	Within-subject design. T2 and T3 were counterbalanced. T1 = Control T2 = Competition T3 = Control.	Cycling Time to exhaustion on an ergometer.	Head-to-head competition against a matched participant, as well as their previous performance time.	Time to exhaustion and total work were greater ($p < .05$) in the competitive trial (T2 time = 457 ± 233 s) than when Ps performed alone (T3 = 379 ± 180 s). $\Delta = 0.41$.
Mental fatigue	MacMahon, Schücker, Hagemann, & Strauss (2014)	20 experienced runners (f = 2, m = 18, age = 25.4 ± 3.2).	Within-subject design. Order of conditions was assigned randomly.	Running Performance time in a 3 km time trial on an indoor track.	Pre-performance intervention. Demanding 90-minute cognitive task (replication of Marcora, Staiano, & Manning, 2009).	Completion times were slower ($p = .009$) in the mental fatigue condition (12:11 ± 0:54) compared with the control (11:58 ± 0:48). $\Delta = 0.27$.

(continued)

Table A3 (*continued*)

Psychological determinant	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Mental fatigue (continued)	Marcora, Staiano, & Manning (2009)	16 adults involved in regular aerobic training (f = 6, m = 10, age = 26 ± 3).	Randomised, controlled, crossover experimental design.	Cycling Time to exhaustion on an ergometer.	Pre-performance intervention. Demanding 90-minute cognitive task that requires sustained attention, working memory, response inhibition, and error monitoring.	Time to exhaustion was lower (p = .003) in the mental fatigue condition (640 ± 316 s) than the control condition (754 ± 339 s). Δ = 0.34.
	Pageaux, Lepers, Dietz, & Marcora (2014)	12 physically-active adults (f = 4, m = 8, age = 21 ± 1).	Randomised crossover experimental design with a familiarisation trial.	Running Performance time in a 5 km time trial on a treadmill.	Pre-performance intervention. Demanding 30-minute cognitive task with or without response inhibition.	Mental exertion involving response inhibition impaired (p = .008) time-trial performance (24.4 ± 4.9 min) compared to mental exertion without inhibition (23.1 ± 3.8 min). Δ = 0.34.
Priming	Blanchfield, Hardy, & Marcora (2014) Experiment 1	13 recreationally-trained adults (f = 6, m = 7, age range = 18-23).	Randomised and counterbalanced crossover experimental design.	Cycling Time to exhaustion on an ergometer.	Subliminally-presented visual cues relating to affect (happy or sad faces). Cues were presented during performance.	Ps cycled for 12% longer (p = .04) when subliminally primed with happy faces than sad faces. Cohen's d = 0.26.
	Blanchfield, Hardy, & Marcora (2014) Experiment 2	One male regional-level endurance athlete (age = 22).	Single-subject blocked randomisation tests design (12 experimental trials).	Cycling Time to exhaustion on an ergometer.	Subliminally-presented word cues relating to action (action, go, lively, energy) or inaction (stop, toil, sleep, tired). Cues were presented during performance.	Subliminal priming with action words increased (p = .04) time to exhaustion by 18.3% compared to inaction words.

(continued)

Table A3 (*continued*)

Psychological determinant	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Priming (continued)	Hodgins, Yacko, & Gottlieb (2006)	41 collegiate rowers (f = 24, m = 17).	Between-subjects design with random assignment.	Rowing Performance time in a 2 km time trial on an ergometer.	To prime autonomy, control, or impersonal motivation orientations, Ps used five words to construct grammatically-correct sentences.	Autonomy-primed rowers performed faster than control-primed and impersonally-primed rowers (p = < .05).
Talking	Franks & Myers (1984) Study 1	16 college students (f = 8, m = 8).	Within-subject design. Order of conditions was assigned randomly.	Running Exercise time in an incremental test on a treadmill.	Answering questions about physical activity habits during performance.	There was not a significant difference (p > .10) in time to exhaustion between the talking (10.9 ± 3.1 min) and control (11.2 ± 3.1 min) conditions. Δ = -0.10.
Verbal encouragement	Chitwood, Moffatt, Burke, Luchino, & Jordan (1997)	26 university students (f = 13, m = 13, Type A age = 21.7 ± 0.5, Type B age = 21.7 ± 0.4).	Within-subject design. Order of conditions was assigned randomly.	Running Exercise time in an incremental test on a treadmill.	Verbal encouragement during performance.	Type Bs ran for longer (p < .05) in the encouragement condition (12.5 ± 5.0 min) than the control condition (10.8 ± 3.8 min). Δ = 0.45. Performance times for Type As were similar in the encouragement (12.7 ± 4.2 min) and control (12.6 ± 3.7 min) conditions (p > .05). Δ = 0.03.

(continued)

Table A3 (*continued*)

Psychological determinant	Study	Participant information	Design overview	Exercise mode and performance variable	Experimental intervention	Effect on endurance performance
Verbal encouragement (continued)	Moffatt, Chitwood, & Biggerstaff (1994)	14 inter-collegiate cross-country runners and 14 non-athletes (f = 8, m = 20, athlete age = 21.8 ± 1.4, non-athletes = 23.2 ± 4.7).	Within-subject design. Order of conditions was assigned randomly.	Running Exercise time in an incremental test on a treadmill.	Verbal encouragement during performance.	Competitive runners ran for longer ($p < .05$) in the encouragement condition (19.7 ± 1.2 min) than the control condition (16.7 ± 1.1 min). Δ = 2.73. Non-athletes also ran for longer ($p < .05$) in the encouragement condition (14.3 ± 0.9 min) than the control (12.4 ± 1.2 min). Δ = 1.58.
	Viru et al. (2010)	14 male university-level endurance athletes (age range = 19-23).	Within-subject design. Order of conditions was assigned randomly.	Running Exercise time in an incremental test on a treadmill.	Monetary incentives to better their own time and the times of others, as well as strong encouragement.	Ps ran for longer ($p < .05$) in the competitive condition (1,222 ± 100 s) than the control condition (1,173 ± 121 s). Δ = 0.40.

Note. f = number of female participants; m = number of male participants, M = mean; P(s) = participant(s), post = number of post-intervention performances, pre = number of pre-intervention performances; T = trial; Type A / B = Type A / B personality participants; ± = mean ± standard deviation; Δ = effect size (Glass' delta);

Appendix F

Example Participant Characteristics Questionnaire (Chapter 3)

Focus Group Participant Information

Participant ID Number:

Please answer the below questions as accurately as you can. Approximate if you cannot answer a question with specific details. If you do not wish to answer a question, please leave it blank. Information that you provide shall be treated as confidential, as detailed in the *Participant Information Sheet*.

Age: Gender: Nationality:

How many years have you been involved in triathlon, including recreational (non-competitive) involvement?

On average, how many hours do you train each week?

Approximately how many weeks do you train each year?

Which club(s) do you train with?

How many years have you been taking part in triathlon competitions / races?

What is your main competitive distance (this can be a single distance or a range of distances):

How many years have you been competing at your main competitive distance?

If your main competitive distance is Ironman / long distance, how many years have you competed at sprint and middle distances?

How many times have you competed in triathlon competitions (any distances) over the previous 12 months?

3-5 6-10 11-15 16-20 21 or more

When was the most recent time that you competed?

Could you estimate how many times you have competed in triathlon races (any distances) in total?

3-5 6-10 11-20 21-50 51-100 101 or more

Which of the below best describes the level or standard of competitions that you currently enter?

Local University Regional National International Other (please state)

……………………

What is the highest level or standard that you have competed at?

Local University Regional National International Other (please state)

……………………

What is your personal best time in your main competitive distance? Please provide the approximate distance, performance time, and date.

Appendix G

Reflections on Potential Biases (Chapter 3)

Before each focus group, the facilitator reflected on expected topics of discussion, themes they hoped would and would not emerge, and questions they perceived to be more important or more interesting. The notes taken during this reflective exercise are presented.

Exploration of Biases

<u>What do I hope to hear?</u>

Notes written before the pilot focus group:

- I would like to learn that the psychological demands experienced during competition are similar across sports and across competitive levels. This finding would help me to present a simpler results section and to justify using the same intervention across different sports. It would also help me to justify including different populations of participants.
- The psychological demands during competition relate to pain, discomfort, fatigue, and motivation.
- Boredom and lack of motivation are key issues during training / during the build-up to competition.
- I'd also like to hear about self-efficacy (perhaps through the words confidence or belief) before and during competition.
- Stressors could also be interesting before performance.
- It would be interesting to hear about the effect of injuries or needing the toilet during competition.

Additions before the long-distance triathlon focus group:

- Boredom during long-distance competition.
- Injuries and physical discomforts during training.
- Injuries and physical discomforts during competition, because it is such a long distance.
- Self-efficacy (perhaps through the words confidence or belief) before and during competition might relate to confidence in yourself to "race your own race" or to achieve your goals.
- Concentration, particularly relating to pacing strategy. Perhaps concentrating on your physical sensations.
- I would like all focus groups to refer to the importance of proper pacing.
- Family / work commitments stand in the way of ideal training.

Additions before the running focus group:

- “Being up for it” before competition was an interesting and recurring theme in Wednesday’s focus group. I would be interested to hear about this again.
- Self-expectations during competition was an interesting and recurring theme on Wednesday. I would be interested to hear about this again.
- Pain / hurt was a key issue on Wednesday. I would be pleased for this to surface in each group.
- Pacing. Although this was not discussed in depth on Wednesday, it was referred to. I think that this would be an interesting finding if it consistently came up across sports.
- Injuries and discomforts during training and competition.
- When I observed training, the coach varied the activities and included competition to keep things interesting. Boredom and lack of motivation could be important issues during training.
- Self-efficacy before and during competition. This was not particularly discussed on Wednesday, but perhaps it is more important during shorter distances when competitors are close together.
- A key psychological characteristic could be “bloody-mindedness” or “mental toughness” relating to pain and discomfort. This came up in the pilot focus group, and it also came up on Wednesday.

Additions before the cycling focus group:

- Pain and pacing. These are the two main issues that seem to keep coming up. My ears are drawn to these words.
- “Pain” particularly includes references to pain, soreness, hurting, or tiredness in the leg muscles.
- Setting and maintaining your pacing strategy (e.g., not going too fast too early).
- I would like to hear some kind of reference to feeling optimal before competition, such as “being up for it” or confident.
- Some runners inadvertently psyched themselves out through negative self-talk before and during competition. Negative self-talk would be an interesting theme if it consistently emerged. However, I think that this group will be older so it feels like negative self-talk is unlikely to be a key issue this evening.
- Self-efficacy. I would be interested to inform my first intervention using a particular theory. Self-efficacy, self-belief, and confidence have come up a little in the focus groups so far, as well as in my systematic literature review. The cyclists might discuss confidence in yourself to “race your own race” or to achieve your goals.
- Concentration, particularly relating to pacing strategy, would also be very interesting. However, I don’t think there has been much reference to this in the focus groups so far.
- Boredom and lack of motivation could be important issues during longer training sessions.

Additions before the triathlon focus group:

- Pain could be a greater demand in the running section, as suggested by the long-distance triathletes.
- Motivation for training seems to be a consistent theme (i.e., the challenge is "getting out of the house", not the training itself). Finding the time to train because of work and family commitments has consistently emerged. Numerous participants said that endurance athletes need to be selfish if they are to excel.
- Mental preparation for competition seems to mainly involve controlling the controllables (e.g., diet, knowing the performance route, knowing where to park the car) and feeling confident that you've done all that you can. These three themes have come up a lot and would be an interesting finding to present. I do expect some reference to them again tonight.
- I would like to hear people talking about similar demands despite the distance. There may be people who compete in sprint distances and IronMan distances present this evening – I would like to hear that they have similar experiences.
- I am more interested in similarities across focus groups than differences between focus groups.

<u>What do I hope not to cover?</u>

Notes written before the pilot focus group:

- Anxiety plays a key role in performance.

Additions before the running focus group:

- Before the previous interview, I answered this question as "Anxiety plays a key role in performance". As this is a shorter distance, I think this might be an important topic, perhaps relating to self-confidence. I would be quite interested to cover this topic today.

Additions before the cycling focus group:

- Anxiety does not seem to have emerged as an issue, and I feel less opinionated about this presently.
- I am particularly interested in demands that are experienced across sports, competitive levels, and ages. I should be careful not to make a quick judgment of "This is not endurance-specific". Instead, I could allow others in the group to comment on whether they have had a similar experience.

Is there anything else important that I think might come up?

Additions before the running focus group:

- As this is a club with an involved coach, the coach might take responsibility for logistical issues regarding competition.
- Instead, expectations relating to the coach could come up. This might not be discussed, however, as the focus group is held at the coach's house.
- The club has organised training sessions, which might mean that participants do not need to be as "self-motivated" to train. Instead, it could be difficult to juggle training and employment commitments.

Additions before the cycling focus group:

- Finding time to train, being motivated to leave the house and travel to training, and work / family commitments interfering with training are quite likely to be discussed.

Additions before the triathlon focus group:

- I am expecting some of the demands to vary depending on which leg it is (e.g., greater discomfort later on, water in mouth and fighting for space during swimming, bike problems such as punctures during cycling). I should ask whether the leg affects the demands, but I should not force the issue. However, I also think that certain issues will be consistent across legs (e.g., physical discomforts, adjusting pacing, concentration, feeling "up for it").

Are any questions "more important" or "more interesting"?

Notes written before the pilot focus group:

- I am more interested in the demands faced during competition. I therefore risk rushing through the questions about the demands experienced before competition.

Additions before the running focus group:

- I am more interested in the demands faced during competition. The previous focus group jumped between questions, however, so I feel more confident that I will have time to cover all questions. The mental demands of training are likely to be covered before mental preparation for competition, so I should be careful to allow sufficient time to cover the demands experienced when preparing for competition.

Additions before the cycling focus group:

- Based on the topics of discussion in the previous focus groups, I am particularly interested in the mental demands of endurance competition and mental preparation immediately before competition. I should be careful to allow plenty of time for all questions.

Additions before the triathlon focus group:

- Themes seem to be emerging for training, preparation, and competition so I do not think that any of these questions are more important than the others. I should allow enough time for each question and move on once new points are no longer made. In other words, I need to be careful not to prolong the discussion in the hope that recurring themes from other sports come up.

<u>Specific Questions on the Interview Guide</u>

"What do you feel are the mental demands that you face, if there are any, when you are training for your sport?"

What am I expecting to be told about? Notes written before the pilot focus group:

- Lack of motivation before training, particularly when tired mentally or physically, when it is cold and raining (i.e., weather-related) and when busy (i.e., you have other things to do).
- Temptation to finish training early.
- Not wanting to run alone. No one to encourage you!
- Boredom / lack of challenge / "going through the motions" / "Competition feels far away".
- Running despite slight injuries / slight physical discomfort.
- Likely to describe dissociative cognitive strategies (e.g., listening to music, thinking about personal problems or things that are on your mind).
- I expect some reference to goal setting.
- Extrinsic motivation – Not training for enjoyment but so that you are ready for the competition.

"Perhaps you could tell me about the mental demands that you experience, if there are any, during the months before a competition?

What am I expecting to be told about? Notes written before the pilot focus group:

- Maintaining motivation for training when the event is far away.
- Not wanting to wait until the competition – wanting to compete now.
- Perhaps trying to achieve the training or competition goals that mean that you are "on target" for a competition time.
- Self-doubt about whether you can achieve your competition goal.
- I wouldn't be surprised to hear about visualisation at this stage. For example, visualising yourself achieving your goal.
- Possibly pressure from a coach.
- Performance expectations from someone else or expectations that you hold for yourself.
- Possibly tiredness / boredom from repetitive training.
- Possibly slight anxiety thinking about competition.
- I am expecting the answers to be more sport-specific than the answers to later questions.

- I am more interested in the demands faced during competition. I therefore risk rushing through these questions.

"Do these demands change as competition gets closer?"

What am I expecting to be told about? Notes written before the pilot focus group:

- Anxiety could become more intense.
- Less boredom as competition draws closer (more excitement).
- Greater emphasis on being optimally prepared physically and mentally. Periodisation of training. Resting. More imagery perhaps.
- Greater focus on competition goals.
- Physical tiredness because of the training.
- Build up of injuries / increasing physical discomfort.
- Athlete starts to think about their competition more. Planning their strategy. Thinking more about what the venue will look like. Beginning to imagine the event – perhaps anxiety is increasing.
- Motivation increases as the competition gets closer.

"Could you tell me about the demands that you face during the days preceding competition?"

What am I expecting to be told about? Notes written before the pilot focus group:

- Staying well-rested, mentally as well as physically.
- Mentally preparing whilst physically resting. Planning your strategy / visualising strategy implementation and achievement of goals.
- Focus on goals.
- Self-doubt – questioning whether you achieve your goals and whether the hard work would be worth it.
- Preparing food / drinks / last-minute paperwork / travel to competition (some of these would also happen during the weeks before, depending on the urgency of the preparation). The athlete might feel stressed if this preparation is not complete.
- Making sure that you've eaten the right foods / drank right fluids over the week before.
- Perhaps pressure associated with a coach.

"Could you tell me about the demands that you face on the day of competition?"

What am I expecting to be told about? Notes written before the pilot focus group:

- Final preparation (packing food / drinks, driving to competition).
- Good night's sleep before so that you are well-rested.
- Worry if some preparation was not optimal (e.g., disruption of sleep, change in diet, being ill).
- Low-intensity anxiety (but consider individual differences).
- Focusing on goals / visualisation.
- Negative self-talk / self-doubt (e.g., whether they can achieve their goals).

"Could you tell me about the demands that you face immediately before competition?"

What am I expecting to be told about? Notes written before the pilot focus group:

- Increasing anxiety.
- Increasing self-doubt (relating to performance or outcome).
- Negative self-talk – difficulty concentrating and "staying in the moment".
- Psyching yourself up.
- Excitement – Perhaps trying to calm yourself down.
- Frustration – Wanting to start but lots of waiting around.
- Personal issues on your mind – Trying to focus on the competition.
- Not feeling "up for it".

"What are the mental demands that you face during competition?"

- I am biased towards this question, because I find this to be of most interest. There is a risk that I will rush through the other questions and focus on this particular question.
- I am hoping that the mental demands will be similar across sports. I could therefore be biased towards confirming this.

What am I expecting to be told about? Notes written before the pilot focus group:

- Pain, fatigue, discomfort, and injury, leading to possible drops in motivation.
- Body not "feeling right" and falling behind expected performance.
- Self-doubt / low self-confidence in ability to achieve performance / outcome goal.
- Pain, fatigue, discomfort and injury-related sensations might increase during the race. Motivation might be high originally, lower in the middle (they are tired with a long way to go), and high towards the end ("nearly there!").
- Self-confidence might change depending on how well you've started and how well you're doing. Being behind your target time, being behind an athlete of similar ability, or your body not feeling right could lead to reductions in self-confidence and vice versa.
- I imagine that each leg of the triathlon will have different mental demands, but I am unsure what they will be. The origin of pain and discomfort might change.

- Cognitive strategies will become more associative with time, alongside increases in pain, fatigue, and discomfort.

"With these demands in mind, what (mental) characteristics do you think are needed, if there are any, to excel in (specific sport and distance) competition?

What am I expecting to be told about? Notes written before the pilot focus group:

- Unshakeable self-belief.
- Mental toughness.
- Motivation.
- Perhaps concentration.
- Perhaps pain tolerance.
- I would be less interested in hearing about anxiety.

Appendix H

Participant Information Sheet and Consent Form (Chapter 3)

The Psychological Demands of Endurance Competition

Alister McCormick, School of Sport and Exercise Sciences

You are being invited to take part in a research study. Before you decide if you would like to take part, it is important that you understand why the research is being conducted and what it involves. Please take your time to read the following information. Please ask if there is anything that is not clear or if you would like more information.

This research study has been approved by the University of Kent School of Sport & Exercise Sciences Ethics Committee.

What is the purpose of the study?

We are interested in learning about the mental demands and mental challenges that endurance athletes face before and during competition. As little research has been conducted on this topic, we would like to share our findings by publishing them in a research journal. This research study and its findings shall also contribute towards my PhD project.

Why have I been chosen?

We are interested in learning about the mental demands of competing in endurance events (i.e., sports that require athletes to maintain effort over a long distance). You have been chosen because you have competed in three or more endurance events and at least one of these was within the last 12 months.

Do I have to take part?

No. It is up to you to decide whether or not you would like to take part. If you agree to participate and then change your mind, you are still free to withdraw at any time without giving a reason and this would not affect your rights.

What do I have to do?

You will be invited to attend a focus group with other athletes who compete in your sport. You will also be given this information sheet and you will be asked to sign a consent form. A focus group is a group interview. I (Alister McCormick) will lead the focus group. I will ask questions to the group as a whole and I will encourage everyone to participate. These questions will be about your experiences of competing in an endurance event. I will try to understand which experiences the group have in common and which of your experiences are different.

The focus groups shall be run in a quiet and safe location at a convenient time and location. Focus groups will include between five and twelve athletes. I anticipate that the focus group will last for approximately one hour. However, please allow two hours for your involvement, excluding travel. I will record the focus group discussions using an audio tape recorder and I will transcribe and analyse the topics of discussion afterwards.

Are there any risks / benefits involved?

Participation is on a voluntary basis. The focus group offers you the opportunity to participate in a research study, as well as the opportunity to meet and discuss your experiences with individuals who share involvement in endurance sports. I am also able to provide all participants with a booklet on psychological techniques and strategies that have research support and that could be valuable during training, during preparation for endurance competition and during performance itself. The questions that I will ask during the group interview focus on your typical competitive experiences and are not anticipated to cause distress or discomfort. No questions will be asked on sensitive or private topics. However, if you do not wish to answer any particular questions then you will not be expected to.

Will my taking part in the study be kept confidential?

Yes. Each participant shall be assigned a false name for the purposes of data storage, data analysis and publication of findings so that nobody will identify who you are. When I write-up my findings, I may wish to use some anonymous quotes from the focus groups. However, I will not publish any information that might "give away" who you are.

All data shall be looked after in line with the Data Protection Act (1998). Audio recordings of the focus groups, word processed transcriptions of the audio files, and signed consent forms shall be kept for five years and they shall then be destroyed. Electronic data will be stored in a password-protected computer file. Hard data shall be stored in a locker at the university. Only I and my supervisors at the university have access to your data. Audio files, or anonymised word processed transcriptions, of the focus groups may be shared with a research journal to prove that our data is genuine.

Contact Details of Researcher

If you think of any questions before or after the focus group then please contact me by email (AM801@kent.ac.uk) or telephone (07875 135854). Alternatively, you can contact my supervisor, Carla Meijen, by email (c.meijen@kent.ac.uk) or telephone (01634 888816).

Please also contact me if you would like to be provided with information about the findings of the study. Alternatively, please provide me with your contact details and I will gladly provide you with a written copy of the group findings in due course.

The contact details for the School of Sport and Exercise Sciences are:

School of Sport and Exercise Sciences
University of Kent
The Medway Building
Chatham Maritime
Kent, ME4 4AG

Telephone: 01634 888858

Thank you for reading this sheet and for considering whether to take part in the project.

Title of project: The Psychological Demands of Endurance Competition

Name of investigator: Alister McCormick

Participant Identification Number for this project:

Please initial box

1. I confirm that I have read and understand the information contained on the accompanying *Participant Information Sheet* for the above study. I have had the opportunity to consider the information, to ask questions and I have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. Alister McCormick can be contacted by telephone (07875 135854) or email (AM801@Kent.ac.uk) ☐

3. I am aware that the focus group is audio recorded for the purpose of analysing the content of our discussions and I am happy to proceed. ☐

4. I understand that my responses will be anonymised before analysis (I will be given a false name and identifying information will be removed). I give permission for members of the research team to have access to my anonymised responses. ☐

5. I am aware that the researcher intends to publish the results from this research study and that anonymised direct quotes will be included in the publication. I am aware that this publication will not include identifying information. ☐

6. I understand that anonymised audio files, or word processed transcriptions, of the focus groups may also be disclosed to a research journal to prove that the research findings are genuine. ☐

7. I agree to take part in the above research project. ☐

Name of participant	Date	Signature
Name of person taking consent *(if different from lead researcher)*	Date	Signature
Lead researcher	Date	Signature

To be signed and dated in the presence of the participant

Appendix I

Interview Schedule (Chapter 3)

Introduction to research topic

"Today, we are interested in finding out more about the mental demands or mental challenges that endurance athletes face before and during competition. I would like to talk to you about the thoughts and feelings that you experience during training, when preparing for competition and when competing in (specific sport and distance). Throughout the interview, you may find that it helps to think back to specific experiences that you can remember well."

Opening / familiarisation question

"However, firstly, I would like to hear about what you enjoy about competing in (specific sport and distance)."

Could you describe to me what it is that you currently enjoy about competing in (specific sport and distance)?

- Detail probes

Key Questions

"(Specific sport and distance) has particular mental demands. Firstly, I would like to ask about the mental demands that you face during training. What do you feel are the mental demands that you face, if there are any, when you are training for your sport?"

- Could you describe an example of when you experienced this?
- Summarise at end.

“We have discussed the mental demands faced during training. Next, I would like to learn about the mental demands or challenges that you face in the build-up to competition. First, perhaps you could tell me about the mental demands that you experience, if there are any, during the months before a competition?

- Summarise. Do these demands change as competition gets closer?
- Summarise. Could you tell me about the demands that you face during the days preceding competition?
- Summarise. Could you tell me about the demands that you face on the day of competition?
- Summarise. Could you tell me about the demands that you face immediately before competition?
- Specific examples / Contrast probes
- Would the participants like to add or clarify anything?

“You’ve given me a lot of information about your experiences before competing. Let me now turn to how you are feeling during competition. You may find that it helps to think back to specific experiences that you can remember well. What are the mental demands that you face during competition?”

- Could you describe an example of when you experienced this?
- Does the stage of competition influence the mental demands that you face?

“We have discussed the mental challenges that you face in training, during the build up to competition and during competition itself. With these demands in mind, what (mental) characteristics do you think are needed, if there are any, to excel in (specific sport and distance) competition?

<u>Closing Questions</u>

“Is there anything else that you think is important that we have not discussed?”

“What should I have asked you that I did not think to ask?”

Probes

Elaboration probes:

- Can anyone else relate to this experience?
- Can you provide an example of that?
- Can you describe an example of when you experienced this?
- Can you tell me more about that?
- What were you thinking about when this happened?
- How did you feel when this happened?
- How long did you experience this for?
- What do you think led to this experience?

Contrast probes:

- How does this experience relate / compare to...

Detail probes:

- What were you thinking / feeling

Clarification probes.

Notes:

As suggested by Patton, consistently encourage the athletes to mentally revisit a competition ("Think back to a recent competition").

Be ready to ask, "Was there anything specific about this particular competition that contributed to your experience?" For example, is pain always an issue (is it a normal experience) or was pain an issue because it was a longer event and they were underprepared? Perhaps motivation was important because of the type of event (e.g., major versus minor competition).

Make sure you learn what terms mean to an athlete. If they say the words "motivation", "fatigue", "pain", "discomfort", "boredom", etc, explore these – "What does motivation mean to you? Can you describe that experience? Can you put into words what this pain feels like?" There is a real opportunity to gain descriptive, rich data here. Explore their understanding!

Seek clarification using "for someone not familiar with endurance". "For someone not familiar with endurance, what does this pain feel like?"

If an athlete refers to coping strategies they use (e.g., dissociation), ask what it is that they are trying to cope with.

What do I need to say before we start?

Setting the scene:

- Introduce other researchers present if applicable.
- Make participants aware of how to locate toilets.
- Explain what to do if they wish to leave early.
- Explain why tape recorders are being used.
- Explain that the aim of focus groups is to encourage people to talk to each other rather than to respond to a question one-at-a-time.
- Encourage participants to talk to one another, ask questions, exchange anecdotes and comment on each others' experiences and points of view.
- Point out that I may take a backseat approach at first and "eavesdrop".

Expectations:

- Talk one person at a time.
- Allow others to complete their sentences before you start.
- Speak clearly.
- Please understand that I may interrupt to keep the interview focused.
- I will take notes during the interview. Don't worry about this. "I can't remember everything!"
- Encourage them to focus on the conversation if they see me taking notes.
- Throughout the interview, you may find that it helps to think back to specific experiences that you can remember well. Take a few seconds to think through the question before you answer it, particularly thinking back to a recent experience that you can remember well. Encourage participants to visualise / re-experience the situation of interest before asking the question.
- I am new to endurance and you are the experts. Do not expect me know the things that you are used to. Also, I might ask for clarification.
- Differences in opinion are natural in this context. There are no right answers and I'm interested in similarities and differences.
- I am interested in the opinions of all so I will look to involve all, perhaps through specifically asking you a question.

Appendix J

Participant Characteristics Questionnaire (Chapter 4)

Training Background

Please answer the below questions as accurately as you can. Approximate if you cannot answer a question with specific details. If you do not wish to answer a question, please leave it blank. Information that you provide shall be treated as confidential, as detailed in the *Participant Information Sheet*.

Age: Gender: Nationality:

On average, how many days do you train each week?

On average, how many hours do you train each week?

Approximately how many weeks do you train each year?

Do you participate in endurance competitions (e.g., running, cycling, triathlon)?

Yes No

If yes:

What sport do you compete in?

Which of the below best describes the level or standard of competitions that you currently enter?

Recreational/local Regional University National Other (please state)

How many years have you been taking part in competitions / races?

What is your main competitive distance(s)?

How many times have you competed (any distances) over the previous 12 months?

0-2 3-5 6-10 11-15 16-20 21 or more

Appendix K

Laboratory Visit Instructions and Compliance Checklist (Chapter 4)

PRE-VISIT INSTRUCTION SHEET

Thank you for agreeing to take part in this study. Here are some instructions we hope you will follow as accurately as possible in preparation for your three testing sessions.

Throughout your involvement in the study:

- Please maintain your current aerobic exercise regimen.
- Please maintain your current diet.

Within 24 hours of a laboratory visit:

- Avoid heavy / strenuous exercise.
- Sleep for at least 7 hours.
- Do not consume alcohol.
- Please attend each laboratory visit well hydrated. To do this, please drink 40 ml of water for each kg of body weight during the 24 hours preceding a visit. For your weight, this would be ____________ ml of water.

Within 3 hours of a laboratory visit:

- Avoid caffeine (e.g., tea, coffee, Coca Cola, energy drinks / tablets).
- Avoid nicotine. Therefore, please do not smoke.
- Eat a light meal about 2 hours before the test.

Attending the laboratory:

- Please wear similar clothing for each laboratory visit.
- Report if you have taken any medication or had any acute illness, injury, or infection.

INSTRUCTION SHEET CHECKLIST

Participant ID: Date:

Have you taken any form of medication today?	Yes / No
Do you have any form of illness or infection?	Yes / No
Do you have an injury?	Yes / No

Notes:

Within the last 24 hours:

Have you avoided heavy / strenuous exercise?	Yes / No
Have you slept for 7 hours or longer?	Yes / No
Have you consumed alcohol?	Yes / No
Have you consumed the recommended intake of water?	Yes / No

Notes:

Within the last 3 hours:

Did you eat a light meal about 2 hours before the test?	Yes / No
Have you consumed any caffeine?	Yes / No
Have you smoked?	Yes / No

Notes:

Appendix L

Pre-Participation Health Questionnaire (Chapter 4)

HEALTH QUESTIONNAIRE

Name……………………………………………………………………

Date of Birth……………………………….. Age………………

Please answer these questions truthfully and completely. The sole purpose of this questionnaire is to ensure that you are in a fit and healthy state to complete the exercise test.

ANY INFORMATION CONTAINED HEREIN WILL BE TREATED AS CONFIDENTIAL.

SECTION 1: GENERAL HEALTH QUESTIONS

Please read the 8 questions below carefully and answer each one honestly: check YES or NO.

	YES	NO
1. Has your doctor ever said that you have a heart condition or high blood pressure?	☐	☐
2. Do you feel pain in your chest at rest, during your daily activities of living, or when you do physical activity?	☐	☐
3. Do you lose balance because of dizziness or have you lost consciousness in the last 12 months? (Please answer NO if your dizziness was associated with over-breathing including vigorous exercise).	☐	☐
4. Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	☐	☐

If yes, please list condition(s) here:		
5. Are you currently taking prescribed medications for a chronic medical condition?	☐	☐
If yes, please list condition(s) and medications here:		
6. Do you currently have (or have you had within the past 12 months) a bone, joint or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer NO if you had a problem in the past but it *does not limit your ability* to be physically active.	☐	☐
If yes, please list condition(s) here:		
7. Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐
8. Are you, or is there any chance you could be, pregnant?	☐	☐

If you answered NO to all of the questions above, you are cleared to take part in the exercise test.

Go to SECTION 3 to sign the form. You do not need to complete section 2.

If you answered YES to one or more of the questions in Section 1 - PLEASE GO TO SECTION 2.

SECTION 2: CHRONIC MEDICAL CONDITIONS

Please read the questions below carefully and answer each one honestly: check YES or NO.

		YES	NO
1.	**Do you have arthritis, osteoporosis, or back problems?** If YES answer questions 1a-1c. If NO go to Question 2.	□	□
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking any medications or other treatments).	□	□
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebrae (e.g. spondylolisthesis), and/or spondyloysis/pars defect (a crack in the bony ring on the back of the spinal column)?	□	□
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	□	□
2.	**Do you have cancer of any kind?** If YES answer questions 2a-2b. If NO, go to Question 3.	□	□
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head and neck?	□	□
2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	□	□
3.	**Do you have heart disease or cardiovascular disease? This includes coronary artery disease, high blood pressure, heart failure, diagnosed abnormality or heart rhythm.** If YES answer questions 3a-3e. If NO go to Question 4.	□	□
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking any medications or other treatments).	□	□
3b.	Do you have an irregular heartbeat that requires medical management? (e.g. atrial fibrillation, premature ventricular contraction)	□	□
3c.	Do you have chronic heart failure?	□	□
3d.	Do you have a resting blood pressure equal to or greater than 160/90mmHg with or without medication? Answer YES if you do not know your resting blood pressure.	□	□
3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	□	□

		YES	NO
4.	**Do you have any metabolic conditions? This includes Type 1 Diabetes, Type 2 Diabetes and Pre-Diabetes.** If YES answer questions 4a-4c. If NO, go to Question 5.	☐	☐
4a.	Is your blood sugar often above 13mmol/L? (Answer YES if you are not sure).	☐	☐
4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, OR the sensation in your toes and feet?	☐	☐
4c.	Do you have other metabolic conditions (such as thyroid disorders, current pregnancy related diabetes, chronic kidney disease, or liver problems)?	☐	☐
5.	**Do you have any mental health problems or learning difficulties?** This includes Alzheimer's, dementia, depression, anxiety disorder, eating disorder, psychotic disorder, intellectual disability and down syndrome. If YES answer questions 5a-5b. If NO go to Question 6.	☐	☐
5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking any medications or other treatments).	☐	☐
5b.	Do you also have back problems affecting nerves or muscles?	☐	☐
6.	**Do you have a respiratory disease?** This includes chronic obstructive pulmonary disease, asthma, pulmonary high blood pressure. If YES answer questions 6a-6d. If NO, go to Question 7.	☐	☐
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking any medications or other treatments).	☐	☐
6b.	Has your doctor ever said you blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	☐	☐
6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	☐	☐
6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	☐	☐
7.	**Do you have a spinal cord injury?** This includes tetraplegia and paraplegia. If YES answer questions 7a-7c. If NO, go to Question 8.	☐	☐
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking any medications or other treatments).	☐	☐
7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	☐	☐
7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as autonomic dysreflexia)?	☐	☐

		YES	NO
8.	**Have you had a stroke?** This includes transient ischemic attack (TIA) or cerebrovascular event. If YES answer questions 8a-8c. If NO go to Question 9.	☐	☐
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking any medications or other treatments).	☐	☐
8b.	Do you have any impairment in walking or mobility?	☐	☐
8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	☐	☐
9.	**Do you have any other medical condition which is not listed above or do you have two or more medical conditions?** If you have other medical conditions, answer questions 9a-9c. If NO go to Question 10.	☐	☐
9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?	☐	☐
9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, and kidney problems)?	☐	☐
9c.	Do you currently live with two or more medical conditions?	☐	☐
	Please list your medical condition(s) and any related medications here:		
10.	**Have you had a viral infection in the last 2 weeks (cough, cold, sore throat, etc.)?** If YES please provide details below:	☐	☐
11.	**Is there any other reason why you cannot take part in this exercise test?** If YES please provide details below:	☐	☐

12.	**Please provide brief details of your current weekly levels of physical activity (sport, physical fitness or conditioning activities), using the following classification for exertion level:** **L = light (slightly breathless** **M = moderate (breathless)** **V = vigorous (very breathless)** **Activity Duration (mins.) Level (L/M/V)** **Monday** **Tuesday** **Wednesday** **Thursday** **Friday** **Saturday** **Sunday**

Please see below for recommendations for your current medical condition and sign this document:

If you answered NO to all of the follow-up questions about your medical condition, you are cleared to take part in the exercise test.

If you answered YES to one or more of the follow-up questions about your medical condition it is strongly advised that you should seek further advice from a medical professional before taking part in the exercise test.

SECTION 3: DECLERATION

Please read and sign the declaration below:

I, the undersigned, have read, understood and completed this questionnaire to the best of my knowledge.

NAME: ………

SIGNATURE: ……………………………………………………………DATE: ………………………………………

This health questionnaire is based around the PAR-Q+, which was developed by the Canadian Society for Exercise Physiology www.csep.ca

Appendix M

Participant Information Sheet and Consent Form (Chapter 4)

Effects of Muscular Contraction During Exhaustive Exercise

Alister McCormick, School of Sport and Exercise Sciences

You are invited to take part in a research study. This study has been approved by the University of Kent School of Sport & Exercise Sciences Ethics Committee. Before you decide if you would like to take part, it is important that you understand why the research is being conducted and what it involves. Please take your time to read the following information. Please ask if there is anything that is not clear or if you would like more information.

What is the purpose of the study?

We are interested in learning whether intentionally contracting particular muscles on the body or face influences heart rate data during exhaustive exercise. Little research has been conducted on this topic, and we would like to share our findings by publishing them in a research journal. This research shall also contribute towards my PhD project.

Who can take part in this study?

Healthy individuals who are involved in regular aerobic training, not taking any medication (with the exception of contraceptives), and free from injury can take part. Male participants will be between the ages of 18 and 50, and females will be between 18 and 55.

Do I have to take part?

No. It is up to you to decide whether or not you would like to take part. If you agree to participate and then change your mind, you are still free to withdraw at any time without giving a reason. If you decide to withdraw prior to completion of the study, your data will be destroyed and it will not be included in the analysis.

What do I have to do if I take part?

Participants will visit the laboratory five times within 2-3 weeks. You will be asked to comply with certain instructions during the 24 hours before visits 2 to 5 (e.g., avoid heavy exercise, no caffeine within 3 hours). Each visit will require approximately 75-90 minutes. The total time investment (excluding travel) is estimated to be 6-7 hours spread over 2-3 weeks.

During visit 1, we will ask you to sign a consent form and to complete some questionnaires. We will also weigh and measure you. You will then complete a $\dot{V}O_{2max}$ cycling test, which lasts approximately 15 minutes. This test will allow us to calculate your maximal oxygen uptake, which is a good indicator of your aerobic fitness. This cycling test starts at a low intensity and gets progressively harder until you cannot continue. We will require you to wear a facemask during this fitness test so that we can take measurements of your expired air. The facemask covers your nose and mouth, but it is not uncomfortable and it will not impede your breathing.

Visit 2 is a familiarisation session where you will gain experience with the procedures used during visits 3-5. During these four visits, you will be asked to complete some questionnaires that measure your thoughts and feelings, and you will be asked to contract particular muscles on the body or face while you cycle. We will attach electrodes to your skin so that we can measure the contraction of these muscles. This is a non-invasive, harmless procedure. Electrodes will be placed above your eyebrows and on your right thumb and wrist. We may need to shave the areas where these electrodes are placed, and we will also clean these areas with an alcohol swab.

During visits 2-4, you will complete a cycling test called a time-to-exhaustion test. During a time-to-exhaustion test, you cycle at a constant power output until you cannot continue. Before and after each time-to-exhaustion test, we would like to take a small sample of blood from your finger so that we can analyse the concentration of lactate in your blood (lactate causes muscle ache and fatigue during exercise). To do this, we will use a piece of equipment that looks like a small stapler to prick the skin. The amount of pain and bleeding caused by the skin prick will be minimal; it will be similar to if you prick your finger with a safety pin. We will analyse the blood sample on the same day as the time-to-exhaustion test, and we will dispose of your blood sample immediately after we have analysed it (i.e., your blood sample will *not* be stored). We will ask for your permission before we take this blood sample.

Are there any benefits involved in taking part?

Following your involvement in the study, you will be offered an information booklet on psychological strategies that can be used before or during endurance training or competition. We will also tell you your $\dot{V}O_{2max}$, which is a measure of your aerobic fitness. If you provide me with your contact details, I will gladly provide a written copy of the research findings, which will be written up in a report.

Are there any risks involved in taking part?

During the $\dot{V}O_{2max}$ and time-to-exhaustion cycling tests, you will experience uncomfortable exercise sensations that are typical for high-intensity exercise— You are likely to be familiar with these sensations from your experiences exercising. During or after these tests, you may experience light-headedness, fainting, discomfort, leg cramps, muscle soreness, nausea, and in very rare cases, a cardiac event. These risks, however, are the same during your regular physical activity. For those without underlying heart disease, the risk a cardiac emergency is extremely low. Nevertheless, you will be asked to complete a health questionnaire to assess your suitability for inclusion and to further reduce this risk. At all times, you will be closely supervised by a researcher, and a person trained in first aid will always be on site. There is a small chance of picking up an injury (e.g. muscle strain or pull), and you may also suffer some muscle aches and soreness in the days (usually 12-72 hours) after testing— These are typical consequences of exercise training. To reduce the risk of injury, you will have the chance to warm-up before these exercise tests, and you can warm-down afterwards too. The questionnaires are not anticipated to cause discomfort, but if you do not wish to answer any particular questions, then you will not be expected to.

Will taking part in the study be kept confidential?

Yes. Each participant will be assigned a participant code. These codes will be used instead of names for the purposes of data storage and data analysis so that nobody will identify who you are. Only I and other university researchers involved in the study will have access to your data. When we write-up the findings, we will report group-level data, not individual data.

All data will be looked after in line with the Data Protection Act (1998). Participant questionnaires and signed consent forms will be kept for five years and then destroyed. Electronic data will be stored in a password-protected computer file. Hard data will be stored in a key-operated locker or filing cupboard at the university. Anonymised data may be shared with a research journal to prove that our data is genuine, and anonymised group-level data could be sent to other researchers who wish to analyse the data as part of a larger body of data (a “meta-analysis”).

Contact Details of Researcher

I can be contacted by email (AM801@kent.ac.uk) or telephone (07875 135854) if you think of any questions before or after agreeing to participate. Alternatively, you can contact my supervisor, Carla Meijen, by email (c.meijen@kent.ac.uk) or telephone (01634 888816).The contact details for the School of Sport and Exercise Sciences are:

School of Sport and Exercise Sciences
University of Kent
The Medway Building
Chatham Maritime
Kent, ME4 4AG
Telephone: 01634 888858

Thank you for reading this sheet and for considering whether to take part in the project.

Title of project: Effects of Muscular Contraction During Exhaustive Exercise

Name of investigator: Alister McCormick

Participant Identification Number for this project:

Please initial box

1. I confirm that I have read and understand the information contained on the accompanying *Participant Information Sheet* for the above study. I have had the opportunity to consider the information, to ask questions, and I have had these answered satisfactorily.

2. I understand that my participation is voluntary, and I am free to withdraw at any time without giving a reason. Alister McCormick can be contacted by telephone (07875 135854) or email (AM801@Kent.ac.uk).

3. I understand that all of my data (e.g., questionnaire responses, exercise test data) will be anonymised by assigning me a code name before analysis, and the researchers are interested in group rather than individual responses. I give permission for members of the research team to have access to my anonymised data.

4. I am aware that the researchers intend to publish the results from this study. I am aware that only group data will be published.

5. I understand that anonymised group data may be disclosed to a research journal to prove that the research findings are genuine.

6. I am aware that the researcher will ask for my permission to take a small sample of blood from my finger. This blood sample will be analysed for research purposes and then immediately disposed of.

7. I agree to take part in the above research project.

Name of participant	Date	Signature
Name of person taking consent *(if different from lead researcher)*	Date	Signature

To be signed and dated in presence of the participant

Lead researcher	Date	Signature

Appendix N

Pre- and Post-Performance Questionnaires (Chapter 4)

Effects of Muscular Contraction During Exhaustive Exercise

Pre-Performance Questionnaires

Alister McCormick

Please be aware that your answers will be treated as confidential. During the analysis, we will use your Participant ID Code instead of your name. Only the research team will have access to your responses, and we will look at group responses. Please answer the questions honestly.

If you do not wish to answer any of these questions, leave them blank.

Participant ID code:

Questionnaire 1

Rate your level of agreement with the following statements by circling one of the answers.

"I want to give it everything I have got in the time-to-exhaustion test"

1	2	3	4	5
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

"I can cope with the exertion, pain, fatigue, and discomfort experienced during the time-to-exhaustion test"

1	2	3	4	5
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

Questionnaire 2

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to the word. Indicate to what extent you are feeling this way right now, that is, at the present moment.

Use the following scale to record your answers.

1	2	3	4	5
Very Slightly or Not at All	A little	Moderately	Quite a Bit	Extremely

________________1. Interested

________________2. Distressed

________________3. Excited

________________4. Upset

________________5. Strong

________________6. Guilty

________________7. Scared

________________8. Hostile

________________9. Enthusiastic

________________10. Proud

________________11. Irritable

________________12. Alert

________________13. Ashamed

________________14. Inspired

________________15. Nervous

________________16. Determined

________________17. Attentive

________________18. Jittery

________________19. Active

________________20. Afraid

Questionnaire 3

Below is a list of words that describe feelings. Please read each one carefully. Then cross the box that best describes HOW YOU FEEL RIGHT NOW. Make sure you answer every question.

		Not at all	A little	Moderately	Quite a bit	Extremely
1.	Panicky	❑	❑	❑	❑	❑
2.	Lively	❑	❑	❑	❑	❑
3.	Confused	❑	❑	❑	❑	❑
4.	Worn out	❑	❑	❑	❑	❑
5.	Depressed	❑	❑	❑	❑	❑
6.	Downhearted	❑	❑	❑	❑	❑
7.	Annoyed	❑	❑	❑	❑	❑
8.	Exhausted	❑	❑	❑	❑	❑
9.	Mixed-up	❑	❑	❑	❑	❑
10.	Sleepy	❑	❑	❑	❑	❑
11.	Bitter	❑	❑	❑	❑	❑
12.	Unhappy	❑	❑	❑	❑	❑
13.	Anxious	❑	❑	❑	❑	❑
14.	Worried	❑	❑	❑	❑	❑
15.	Energetic	❑	❑	❑	❑	❑
16.	Miserable	❑	❑	❑	❑	❑
17.	Muddled	❑	❑	❑	❑	❑
18.	Nervous	❑	❑	❑	❑	❑
19	Angry	❑	❑	❑	❑	❑
20.	Active	❑	❑	❑	❑	❑
21.	Tired	❑	❑	❑	❑	❑
22.	Bad tempered	❑	❑	❑	❑	❑
23.	Alert	❑	❑	❑	❑	❑
24.	Uncertain	❑	❑	❑	❑	❑

Effects of Muscular Contraction During Exhaustive Exercise

Post-Performance Questionnaires

Alister McCormick

Please be aware that your answers will be treated as confidential. During the analysis, we will use your Participant ID Code instead of your name. Only the research team will have access to your responses, and we will look at group responses. Please answer the questions honestly.

If you do not wish to answer any of these questions, leave them blank.

Participant ID code:

Questionnaire 4

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to the word. Indicate to what extent you are feeling this way right now, that is, at the present moment.

Use the following scale to record your answers.

1	2	3	4	5
Very Slightly or Not at All	A little	Moderately	Quite a Bit	Extremely

__________________1. Interested

__________________2. Distressed

__________________3. Excited

__________________4. Upset

__________________5. Strong

__________________6. Guilty

__________________7. Scared

__________________8. Hostile

__________________9. Enthusiastic

__________________10. Proud

__________________11. Irritable

__________________12. Alert

__________________13. Ashamed

__________________14. Inspired

__________________15. Nervous

__________________16. Determined

__________________17. Attentive

__________________18. Jittery

__________________19. Active

__________________20. Afraid

Questionnaire 5

Below is a list of words that describe feelings. Please read each one carefully. Then cross the box that best describes HOW YOU FEEL RIGHT NOW. Make sure you answer every question.

		Not at all	A little	Moderately	Quite a bit	Extremely
1.	Panicky	❑	❑	❑	❑	❑
2.	Lively	❑	❑	❑	❑	❑
3.	Confused	❑	❑	❑	❑	❑
4.	Worn out	❑	❑	❑	❑	❑
5.	Depressed	❑	❑	❑	❑	❑
6.	Downhearted	❑	❑	❑	❑	❑
7.	Annoyed	❑	❑	❑	❑	❑
8.	Exhausted	❑	❑	❑	❑	❑
9.	Mixed-up	❑	❑	❑	❑	❑
10.	Sleepy	❑	❑	❑	❑	❑
11.	Bitter	❑	❑	❑	❑	❑
12.	Unhappy	❑	❑	❑	❑	❑
13.	Anxious	❑	❑	❑	❑	❑
14.	Worried	❑	❑	❑	❑	❑
15.	Energetic	❑	❑	❑	❑	❑
16.	Miserable	❑	❑	❑	❑	❑
17.	Muddled	❑	❑	❑	❑	❑
18.	Nervous	❑	❑	❑	❑	❑
19	Angry	❑	❑	❑	❑	❑
20.	Active	❑	❑	❑	❑	❑
21.	Tired	❑	❑	❑	❑	❑
22.	Bad tempered	❑	❑	❑	❑	❑
23.	Alert	❑	❑	❑	❑	❑
24.	Uncertain	❑	❑	❑	❑	❑

Appendix O

Example Experimental Protocol Checklist (Chapter 4)

<u>Experimental Trials Checklist</u>

Participant ID	
Date and time	
Laboratory Conditions	
Turn air conditioning on (18 degrees C)	
Laboratory temperature	
Laboratory humidity	
Barometric pressure	
Lactate equipment ready? Machine on?	
Saddle specification	Vertical –
Handlebar Set vertically	
EMG Equipment and Protocols	
Completed instructions compliance checklist?	
Has their health or injury status changed?	
MVC x 3 (Corrugators / thenar muscles – FLIP COIN)	
Mean value	
10% MVC value	
MVC x 3 (Corrugators / thenar muscles)	
Mean value	
10% MVC value	
Re-familiarise with the RPE scale (walk + water)	
Re-familiarise with corrugator 10% (1 minute)	Notes:

Re-familiarise with thenar 10% (1 minute)	Notes:
Set up heart rate monitor	
Lactate sample	
Complete questionnaires	
Intervention Instructions – Face	
Relax arms, fingers around and thumb above handlebar	
"Maintain > 10%. Take short breaks when needed."	
"Keep eyes open"	
Time-to-exhaustion Test	
Turn on fan (middle setting)	
Record on EMG (flag events)	
Turn on voice recorder	
Resting heart rate	
"Please offer your best performance"	
"Remain in the saddle at all times"	
Exhaustion = Less than 60rpm for 5 secs (60-100 RPM)	
3 min warm-up at 20W	
30-second break	
Time to exhaustion at 60% delta	Workload = W
Exercise duration	
Flag on EMG	
Lactate (3 mins post)	
PANAS / BRUMS	
NASA-TLX Subscales + Weights	

Minute	Cadence	Heart Rate	RPE	Feeling	“Up”
At rest					
Minute 2 of warm-up					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Exercise duration	
Lactate (3 mins post)	

Appendix P

Instructions for the Ratings of Perceived Exertion Scale (Chapter 4)

Instructions for the Ratings of Perceived Exertion (RPE) Scale

We want you to rate how <u>effortful, heavy, and strenuous the exercise feels</u> to you. We call this perceived effort or perceived exertion. Perceived effort depends mainly on how hard you have to drive your legs and how heavy your breathing is. It does NOT depend on muscle pain (i.e., the aching and burning sensation in your leg or arm muscles).

Look at the scale below. We want you to use this scale from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion".

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

To help you choose a number that corresponds to how you feel within this range, consider the following:

- 9 Very light. As for a healthy person taking a short walk at his or her own pace.
- 13 Somewhat hard. It still feels OK to continue.
- 15 It is hard and tiring, but continuing is not terribly difficult.
- 17 Very hard. It is very strenuous. You can still go on, but you really have to push yourself and you are very tired.
- 19 An extremely strenuous level. For most people this is the most strenuous exercise they have ever experienced.

When rating your perceived effort, start with a verbal expression and then choose a number. If your perception of effort is *light*, rate 10, 11, or 12; if it is *very hard*, rate 16, 17, or 18, and so on. You can use even numbers or odd numbers. You could also select a half number.

Try to appraise your subjective feeling of exertion as spontaneously and as honestly as possible, without thinking about the physiological cues or the actual physical load. Try not to underestimate, nor to overestimate. It is very important that you answer what you perceive and not what you believe you ought to answer. It is your own feeling of effort and exertion that is important, not how it compares to other people. What other people think is not important either. There are no right or wrong answers.

Do you have any questions?

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Appendix Q

Feeling Scale (Hardy & Rejeski, 1989) (Chapter 4)

While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable, whereas others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise. Scientists have developed this scale to measure such responses.

+5	Very good
+4	
+3	Good
+2	
+1	Fairly good
0	Neutral
-1	Fairly bad
-2	
-3	Bad
-4	
-5	Very bad

Appendix R

Brunel Mood Scale Values Before and After Performance (Chapter 4)

Table A4

Brunel Mood Scale Values Before and After Performance

Time point	Condition	Tension	Vigour	Confusion	Fatigue	Depression	Anger
Pre-performance	Frowning	1.10 ± 1.10	9.20 ± 2.49	0.20 ± 0.42	2.30 ± 3.23	0 ± 0	0 ± 0
	Thumb press	1.30 ± 1.64	9.30 ± 3.47	0.10 ± 0.32	1.50 ± 2.07	0 ± 0	0 ± 0
	No intervention	1.40 ± 1.65	8.70 ± 3.50	0.10 ± 0.32	1.90 ± 2.08	0 ± 0	0 ± 0
Post-performance	Frowning	0.40 ± 1.26	10.1 ± 4.61	0.60 ± 0.84	6.60 ± 4.33	0.10 ± 0.32	0.10 ± 0.32
	Thumb press	0.80 ± 1.75	9.20 ± 4.39	0.60 ± 1.26	6.00 ± 3.53	0.20 ± 0.63	0.20 ± 0.42
	No intervention	0 ± 0	9.00 ± 4.81	0.20 ± 0.63	6.50 ± 3.44	0.30 ± 0.48	0.30 ± 0.48
Change (Post-pre)	Frowning	-0.70 ± 1.06	0.90 ± 4.56	0.40 ± 1.07	4.30 ± 4.37	0.10 ± 0.32	0.10 ± 0.32
	Thumb press	-0.50 ± 1.35	-0.10 ± 3.70	0.50 ± 1.27	4.50 ± 3.34	0.20 ± 0.63	0.20 ± 0.42
	No intervention	-1.40 ± 1.65	0.30 ± 3.13	0.10 ± 0.74	4.60 ± 3.57	0.30 ± 0.48	0.30 ± 0.48

Note. ± = mean ± standard deviation. Pre-performance and post-performance values can range from 0 to 16. Change values can range from -16 to 16. One-way, repeated-measures ANOVAs (tension, vigour, and fatigue subscales) and Friedman tests of differences among repeated measures (confusion, depression, and anger subscales) indicated that differences in change scores between conditions were not statistically significant ($p \geq .27$).

Appendix S

Adapted NASA-TLX (Chapter 4)

NASA-TLX

Participant Instructions: Rating Scales

We are interested in the experiences you have during the different muscular-contraction tasks. In the most general sense, we are examining the "workload" you experienced. Workload is a difficult concept to define precisely, but a simple one to understand generally. The factors that influence your experience of workload may come from the muscular-contraction task itself, your feelings about your own performance in the muscular-contraction task, how much effort you put into the muscular-contraction task, or the stress or frustration you felt. The workload contributed by different elements of the task may change as you move from one muscular-contraction task to another. Physical components of workload are relatively easy to evaluate. However, the mental components of workload may be more difficult to measure.

Since workload is something that is experienced individually by each person, there are no effective "rulers" that can be used to estimate the workload of different activities. One way to find out about workload is to ask people to describe the feelings they experienced. Because workload may be caused by many different factors, we would like you to evaluate several of them individually, rather than lumping them into a single evaluation of overall workload. This set of six rating scales was developed for you to evaluate your experiences during the different muscular-contraction tasks. Please read the descriptions of the scales carefully. If you have a question about any of the scales in the table, please ask me about it. It is extremely important that the scales are clear to you. You may keep the descriptions with you for reference during the experiment.

After performing each of the muscular-contraction tasks, you will be given a sheet of rating scales. You will evaluate the task by circling a line on each of the six scales at the point which matches your experience. Each line has two endpoint descriptors that describe the scale. Note that "performance" goes from "good" on the left to "poor" on the right. This order has confused some people. Consider each scale individually, and consider your responses carefully. Your ratings will play an important role in the evaluation being conducted— your active participation is therefore essential to the success of this experiment, and it is greatly appreciated by us.

RATING SCALE DEFINITIONS		
Title	Endpoints	Descriptions
MENTAL DEMAND	Low / High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the muscular-contraction task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	Low / High	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the muscular-contraction task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	Low / High	How much time pressure did you feel due to the rate or pace at which the muscular-contraction tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	Good / Poor	How successful do you think you were in accomplishing the goals of the muscular-contraction task set by the experimenter? How satisfied were you with your performance in accomplishing these goals?
EFFORT	Low / High	How hard did you have to work (mentally and physically) to accomplish your level of performance in the muscular-contraction task?
FRUSTRATION LEVEL	Low / High	How secure, gratified, content, relaxed and complacent versus insecure, discouraged, irritated, stressed and annoyed did you feel during the muscular-contraction task?

RATING SHEET

Participant ID: **Date:**

Task:

MENTAL DEMAND

Low High

PHYSICAL DEMAND

Low High

TEMPORAL DEMAND

Low High

PERFORMANCE

Good Poor

EFFORT

Low High

FRUSTRATION

Low High

Participant Instructions: Sources-of-workload Evaluation

Throughout this experiment, the rating scales are used to assess your experiences in the different muscular-contraction tasks. Scales of this sort are extremely useful, but their utility suffers from the tendency people have to interpret them in individual ways. For example, some people feel that mental or temporal demands are the essential aspects of workload regardless of the effort they expended on a given task or the level of performance they achieved. Others feel that if they performed well the workload must have been low and if they performed badly the workload must have been high. Yet others feel that effort or feelings of frustration are the most important factors in workload, and so on. The results of previous studies have already found every conceivable pattern of values. In addition, the factors that create levels of workload differ depending on the task. For example, some tasks might be difficult because they must be completed very quickly. Others may seem easy or hard because of the intensity of mental or physical effort required. Yet others feel difficult because they cannot be performed well, no matter how much effort is expended.

The evaluation you are about to perform is a technique that has been developed by NASA to assess the relative importance of six factors in determining how much workload you experienced. The procedure is simple: You will be presented with a series of pairs of rating scale titles (for example, Effort vs. Mental Demands) and asked to choose which of the items was more important to <u>your</u> experience of workload in the task that you just performed.

<u>Circle the scale title that represents the more important contributor to workload for the specific muscular-contraction task you performed in this experiment</u>

After you have finished the entire series, we will be able to use the pattern of your choices to create a summary workload score. Please use the descriptions of the scales (like you did when you rated each of the six factors), and consider your choices carefully. Don’t think that there is any *correct* pattern; we are only interested in your opinions.

If you have any questions, please ask them now. Otherwise, start whenever you are ready. Thank you for your participation.

Effort	or	Performance
Temporal Demand	or	Frustration
Temporal Demand	or	Effort
Physical Demand	or	Frustration
Performance	or	Frustration
Physical Demand	or	Temporal Demand
Physical Demand	or	Performance
Temporal Demand	or	Mental Demand
Frustration	or	Effort
Performance	or	Mental Demand
Performance	or	Temporal Demand
Mental Demand	or	Effort
Mental Demand	or	Physical Demand
Effort	or	Physical Demand
Frustration	or	Mental Demand

Appendix T

Final Session Questionnaire (Chapter 4)

Final Session Questionnaire

Please rank the three sessions in order of preference by ticking one of the boxes for each session.

	1^{st} favourite	2^{nd} favourite	3^{rd} favourite
Session 1			
Session 2			
Session 3			

In a few sentences, how did you feel during the session that you contracted your facial muscles?

In a few sentences, how did you feel during the session that you contracted your thumb muscles?

In as many or as few words as you wish, please describe what you think was the purpose of this study. In other words, what did it aim to find out?

What do you expect our results to show?

Thank you for your support throughout this study.

Appendix U

NASA-TLX Subscale Scores for the Frowning and Thumb-Press Tasks (Chapter 4)

Table A5
NASA-TLX Subscale Scores for the Frowning and Thumb-Press Tasks

Subscale	Frowning task	Thumb-press task
Mental	13.7 ± 3.91	9.00 ± 5.70
Physical	7.89 ± 4.11	6.11 ± 2.76
Temporal	7.44 ± 5.17	7.56 ± 5.83
Performance	7.11 ± 4.40	5.89 ± 2.57
Effort	11.8 ± 4.84	8.89 ± 5.33
Frustration	8.44 ± 5.88	5.00 ± 4.64

Note. ± = mean ± standard deviation. Values can range from 0 to 20.

Appendix V

Pre-Event Questionnaire (Chapter 5)

Psychological Preparation for a Long-distance Endurance Event

T60 Pre-performance Questionnaires

Alister McCormick

Please be aware that your answers will be treated as confidential. During the analysis, we will use the Participant ID Codes in the top-left corner of the questionnaire instead of participants' names. Only the research team will have access to your responses, and we will look at group responses.

Please answer the questions honestly. Your answers will contribute to us gaining a better understanding of the experiences of T60 runners and help us to evaluate the workbooks.

Questionnaire 1

Please read the below statement and select the box that most accurately represents your opinion.

"The psychological intervention I received has the potential to improve performance in endurance events like the T60."

Very strongly disagree	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Very strongly agree

Questionnaire 2

Please rate your agreement with the following statements. For each statement, circle one of the following answers.

“I am motivated to participate in the T60 Night Race”

0	1	2	3	4
Not at all	A little bit	Somewhat	Very much	Extremely

“I am motivated to race against others in the T60 Night Race”

0	1	2	3	4
Not at all	A little bit	Somewhat	Very much	Extremely

Questionnaire 3

Below you will find a list of words that describe a range of feelings that sport performers may experience. Please read each one carefully and indicate on the scale next to each item how you feel right now, at this moment, in relation to the upcoming competition. There are no right or wrong answers. Do not spend too much time on any one item, but choose the answer which best describes your feelings right now in relation to the upcoming competition. Select one answer on every row.

	0 Not at all	1 A little	2 Moderately	3 Quite a bit	4 Extremely
Nervous					
Unhappy					
Annoyed					
Enthusiastic					
Worn out					
Joyful					
Anxious					
Sad					
Irritated					
Excited					
Exhausted					
Pleased					
Tense					
Upset					
Cheerful					
Apprehensive					
Energetic					
Sleepy					
Dejected					
Furious					
Exhilarated					
Uneasy					
Tired					
Disappointed					
Angry					
Happy					

Questionnaire 4

There are two parts to this questionnaire.

Ten demands or challenges of competing in endurance events are written in the table below. First, please rate how certain you are that you can do each of the 10 things during the T60. For each, rate your degree of confidence by recording a number from 0 to 100 using the scale given below. Write the appropriate number in the boxes in the left half of the table.

0	10	20	30	40	50	60	70	80	90	100
Cannot do at all					Moderately certain can do					Highly certain can do

	Confidence (0 – 100)			No control									Complete control
1. Finish the T60 Night Race	Rating	%		1	2	3	4	5	6	7	8	9	10
2. Pace yourself effectively	Rating	%		1	2	3	4	5	6	7	8	9	10
3. Cope with the experienced effort, pain, fatigue, and discomfort	Rating	%		1	2	3	4	5	6	7	8	9	10
4. Keep pushing yourself physically	Rating	%		1	2	3	4	5	6	7	8	9	10
5. Cope with things going wrong	Rating	%		1	2	3	4	5	6	7	8	9	10
6. Stay motivated	Rating	%		1	2	3	4	5	6	7	8	9	10
7. Continue to concentrate on the right things	Rating	%		1	2	3	4	5	6	7	8	9	10
8. Deal with boredom	Rating	%		1	2	3	4	5	6	7	8	9	10
9. Handle the T60 environmental conditions (e.g., rain, wind, mud, cold)	Rating	%		1	2	3	4	5	6	7	8	9	10
10. Cope with the lack of sleep	Rating	%		1	2	3	4	5	6	7	8	9	10

Second, please use the right half of the table above to rate how much control you perceive yourself to have over each of the 10 demands/challenges. Circle a number from 1 to 10. A rating of 1 indicates no control, and a rating of 10 indicates complete control.

Appendix W

Participant Information Sheet and Consent Form (Chapter 5)

Psychological Preparation for a Long-Distance Endurance Event

Alister McCormick, School of Sport and Exercise Sciences

You are invited to take part in a research study. This study has been approved by the University of Kent School of Sport & Exercise Sciences Ethics Committee. Before you decide if you would like to take part, it is important that you understand why the research is being conducted and what it involves. Please take your time to read the following information. Please ask if there is anything that is not clear or if you would like more information.

<u>What is the purpose of the study?</u>

We are interested in learning whether a consultation with a sport psychologist influences endurance runners' experiences before and during a long-distance event like the T60. We would also like to learn how runners pace themselves in long-distance events. Little research has been conducted on these topics, and we would like to share our findings by publishing them in a research journal. This research shall also contribute towards my PhD project.

<u>Why have I been chosen?</u>

You have been chosen because you have registered to take part in the T60 Night Race.

<u>Do I have to take part?</u>

No. It is up to you to decide whether or not you would like to take part. If you agree to participate and then change your mind, you are still free to withdraw at any time without giving a reason.

<u>What do I have to do if I take part?</u>

You have the opportunity to speak to a sport psychology researcher about your preparation for the T60 Night Race. The researcher will offer advice and suggestions on how to prepare for the event. He will also provide you with a short workbook. This workbook will include tasks for you to practise over a two-week period before the T60 Night Race.

You will be asked to complete the following questionnaires. Most of the questionnaires will be completed online, but the questionnaires completed two hours before the T60 will be completed on paper.

- Two questionnaires during the month before the T60 Night Race. The time commitment should be less than 30 minutes.
- One questionnaire two hours before the T60. This questionnaire will take 5 to 10 minutes to complete.
- One questionnaire on the day following completion of the T60 Night Race. The time commitment should be less than 45 minutes.
- We will contact you six months after the event to ask if you are still following our advice. The time commitment should be less than 10 minutes.

Every five miles during the T60, you will answer three easy questions about how you are feeling by writing three numbers on the route maps supplied by the event organisers. Answering these questions will not interfere with your involvement in the T60.

The T60 organisers have arranged to supply competitors with GPS tags that give real-time information on each competitor's progress, and these GPS tags will record your heart rate if you use a heart rate monitor. We would like your permission to analyse this data; you do not need to do anything.

Are there any benefits involved in taking part?

You will be offered advice and suggestions on mental preparation by a researcher who has training in sport psychology and experience working with endurance athletes. If you would like to read the findings of the study, please provide me with your contact details and I will gladly provide a written copy of the group findings in due course.

Are there any risks involved in taking part?

The questionnaires focus on your typical competitive experiences, and they are not anticipated to cause discomfort. No questions will be asked on sensitive or private topics. If you do not wish to answer any particular questions, then you will not be expected to.

Will taking part in the study be kept confidential?

Yes. Each participating runner will be emailed a participant code to write on their questionnaires. These codes will be used instead of names for the purposes of data storage and data analysis so that nobody will identify who you are. Only I and other university researchers involved in the study will have access to your data. When we write-up the findings, we will report group-level data, not individual data.

All data shall be looked after in line with the Data Protection Act (1998). Participant questionnaires and signed consent forms shall be kept for five years, and they shall then be destroyed. Electronic data will be stored in a password-protected computer file. Hard data shall be stored in a key-operated locker or filing cupboard at the university. Anonymised data may be shared with a research journal to prove that our data is genuine.

Contact Details of Researcher

I can be contacted by email (AM801@kent.ac.uk) or telephone (07875 135854) if you think of any questions before or after the T60 Night Race. Alternatively, you can contact my supervisor, Carla Meijen, by email (c.meijen@kent.ac.uk) or telephone (01634 888816).The contact details for the School of Sport and Exercise Sciences are:

School of Sport and Exercise Sciences
University of Kent
The Medway Building
Chatham Maritime
Kent, ME4 4AG, Telephone: 01634 888858

Thank you for reading this sheet and for considering whether to take part in the project.

Title of project: Psychological Preparation for a Long-distance Endurance Event

Name of investigator: Alister McCormick

Participant Identification Number for this project:

Please initial box

1. I confirm that I have read and understand the information contained on the accompanying *Participant Information Sheet* for the above study. I have had the opportunity to consider the information, to ask questions, and I have had these answered satisfactorily.
2. I understand that my participation is voluntary, and I am free to withdraw at any time without giving a reason. Alister McCormick can be contacted by telephone (07875 135854) or email (AM801@Kent.ac.uk).
3. I understand that my questionnaire responses will be anonymised (by assigning me a code name) before analysis, and the researchers are interested in group rather than individual responses. I give permission for members of the research team to have access to my anonymised responses.
4. I am aware that the researchers will analyse GPS data, including heart rate if I use a heart rate monitor, and the researchers are interested in group rather than individual data.
5. I am aware that the researchers intend to publish the results from these studies. I am aware that only group data will be published.
6. I understand that anonymised group data may be disclosed to a research journal to prove that the research findings are genuine.
7. I agree to take part in the above research project.

Name of participant	Date	Signature
Name of person taking consent *(if different from lead researcher)*	Date	Signature

To be signed and dated in presence of the participant

Lead researcher	Date	Signature

Appendix X

Achievement Goal Questionnaire for Sport (Adapted From Conroy, Elliot, & Hofer, 2003) (Chapter 5)

Consider your thoughts and feelings about endurance events like the T60. Indicate the extent to which the following statements are true of you just before an important endurance event.

I am striving to perform as well as I possibly can.

1	2	3	4	5	6	7

Not at all like me Completely like me

My aim is to avoid not performing as well as I possibly can.

1	2	3	4	5	6	7

Not at all like me Completely like me

I am striving to do well compared to others.

1	2	3	4	5	6	7

Not at all like me Completely like me

My aim is to avoid performing worse than others.

1	2	3	4	5	6	7

Not at all like me Completely like me

My goal is to perform as well as it is possible for me to perform.

1	2	3	4	5	6	7

Not at all like me Completely like me

I am striving to avoid not performing as well as I'd like.

1	2	3	4	5	6	7

Not at all like me Completely like me

My aim is to perform better than others.

1	2	3	4	5	6	7

Not at all like me Completely like me

My goal is to avoid performing worse than other performers.

1	2	3	4	5	6	7

Not at all like me Completely like me

My aim is to master all aspects of my performance.

1	2	3	4	5	6	7

Not at all like me Completely like me

My goal is to avoid not performing as well as I can perform.

1	2	3	4	5	6	7

Not at all like me Completely like me

My goal is to do better than other performers.

1	2	3	4	5	6	7

Not at all like me Completely like me

I am striving to avoid being one of the worst performers in the group.

1	2	3	4	5	6	7

Not at all like me Completely like me

Appendix Y

Instructions for Using Perceived Effort and Pain Scales (Chapter 5)

Note: The sample route map that is referred to is not included in this appendix.

University of Kent

Psychological Preparation for a Long-Distance Endurance Event

T60 Race Scales

Alister McCormick (AM801@Kent.ac.uk)

During the T60, you will be given a number of route maps that look like the map on the following page. You will use these maps to navigate, but you will also be asked to provide three ratings at different locations throughout the race. You will do this by marking numbers onto the maps using marker pens, which will be supplied.

On the left-hand side of this map, you will see two perceived exertion scales. You will be required to select a number that represents your rating of perceived exertion, and you will mark the corresponding box. There are two scales on the left-hand side. These two scales (labelled 1A and 1B) correspond with two locations where you will provide a rating of perceived exertion on this portion of the race. 1A and 1B will be clearly marked on the route map (they are not located on this example map).

On the right-hand side of the map, you will see two exercise-induced pain scales and two injury-related pain scales. You will be required to select a number that represents your rating of exercise-induced pain and a number that represents your rating of injury-related pain, and you will mark the corresponding boxes. You will do this at location 1A and location 1B (as well as locations displayed on subsequent maps).

Therefore, you will tick 3 boxes at location 1A (perceived exertion, exercise-induced pain, and injury-related pain) and 3 boxes at location 1B. You will be asked to do this on each map that you are supplied with, and you will be reminded at checkpoints.

Perceived exertion, exercise-induced pain, and injury-related pain are different experiences. This short information sheet will clarify what is meant by perceived exertion, exercise-induced pain, and injury-related pain, so that you understand what you are being asked to rate.

Instructions for perceived exertion scale

During the race, we want you to rate how effortful, heavy, and strenuous the exercise feels to you. We call this perceived effort or perceived exertion. Perceived effort depends mainly on how hard you have to drive your legs and/or arms, and how heavy is your breathing.

Look at the scale below. We want you to use this scale from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion".

6	No exertion at all
7 8	Extremely light
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

To help you choose a number that corresponds to how you feel within this range, consider the following:

9 Very light. As for a healthy person taking a short walk at his or her own pace.
13 Somewhat hard. It still feels OK to continue.
15 It is hard and tiring, but continuing is not terribly difficult.
17 Very hard. It is very strenuous. You can still go on, but you really have to push yourself and you are very tired.
19 An extremely strenuous level. For most people this is the most strenuous exercise they have ever experienced.

When rating your perceived effort, start with a verbal expression and then choose a number. If your perception of effort is *light*, rate 10, 11, or 12; if it is *very hard*, rate 16, 17, or 18, and so on. You can use even numbers or odd numbers. You could also select a half number. To mark 13 ½ on the map, for example, mark 13 and write ½ next to it.

Try to appraise your feeling of exertion as spontaneously and as honestly as possible, without thinking about what your actual work rate is. Try not to underestimate, nor to overestimate. It is very important that you answer what you perceive and not what you believe you ought to answer. It is your own feeling of effort and exertion that is important, not how it compares to other people. There are no right or wrong answers.

<u>Instructions for pain scales</u>

You will use the same pain scale to rate exercise-induced pain and injury-related pain, but you will rate them separately. The below two sections clarify the difference between these two types of pain.

Exercise-induced pain

You should use the scale to assess the perceptions of pain that arise as a result of exercising. This should be the pain that is produced by muscle burn and ache as a result of repeated or prolonged muscular contraction, and <u>not</u> pain that results from injury (e.g. blisters, twisted ankle, etc.).

Injury-related pain

You should use the same pain scale to assess the perceptions of pain that may arise as a result of injury during the race. This should be the unexpected pain that may result from injury (e.g. blisters, twisted ankle, etc.) and <u>not</u> the expected exercise-induced pain that is produced by muscle burn / ache as a result of repeated or prolonged muscular contraction.

<u>Using these two pain scales</u>

You will use the following pain scale to rate exercise-induced pain and injury-related pain, but you will rate them separately.

0	No pain at all
½	Very faint pain
1	Weak pain
2	Mild pain
3	Moderate pain
4	Somewhat strong pain
5	Strong pain
6	
7	Very strong pain
8	
9	
10	Extremely intense pain (almost unbearable)
o	Unbearable pain

When rating exercise-induced pain and injury-related pain, don't underestimate or overestimate the degree of hurt you feel, just try to estimate it as honestly and objectively as possible. The numbers on the scale represent a range of pain intensity from "very faint pain" (number ½) to "extremely intense pain-almost unbearable" (number 10). When you feel no pain, you should respond with the number zero. When pain becomes just noticeable, you should respond with the number ½. If you feel extremely strong pain that is almost unbearable, you should respond with the number 10. You can also respond with numbers greater than 10. If the pain is greater than 10, respond with the number that represents the pain intensity you feel in relation to 10. In other words, if the pain is twice as great then respond with the number 20 (simply write a number 20 on the map).

You should <u>not</u> use your pain ratings as an expression of fatigue (i.e. inability of the muscle to produce force) or exertion (i.e. how hard it is for you to drive your leg), although increased pain may compromise your willingness to produce muscular force.

<u>Task for training</u>

You will notice that the map on page 2 does not include the descriptions (e.g., "Very light") that relate to the numbers on the scales. Therefore, it is important that you are familiar with the scales. Scales that do include the verbal descriptions will be available at registration and checkpoints so that you can remind yourself.

Please <u>print off</u> the following page and take it with you in your pocket during one or more training run.

Familiarise yourself with the 2 scales before the training run and then rate your perceived effort, exercise-induced pain, and injury-related pain at three or more points during this training run. As a minimum, please note your ratings five minutes into the run, at the half-way point, and five minutes from the end of the run. Remember:

- <u>Perceived effort</u> is how effortful, heavy, and strenuous the exercise feels to you.
- <u>Exercise-induced pain</u> is pain produced by the muscle burn and ache that results from the repeated and prolonged muscular contraction involved in sustained exercise.
- <u>Injury-related pain</u> is pain that may arise as a result of injury during the race (e.g., twisted ankle, blisters).

Training run ratings – Enter into the below table

	5 mins into run		Half way		5 mins from end
Perceived effort (6-20)					
Exercise-induced pain (0-10)					
Injury-related pain (0-10)					

Perceived effort is rated using this scale:

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Exercise-induced pain and injury-related pain are rated using this scale:

0	No pain at all
½	Very faint pain
1	Weak pain
2	Mild pain
3	Moderate pain
4	Somewhat strong pain
5	Strong pain
6	
7	Very strong pain
8	
9	
10	Extremely intense pain (almost unbearable)
o	Unbearable pain

Appendix Z

Information Distributed to Participants on Combining the Interventions (Chapter 5)

Combining Self-talk and the Concentration Grid

Generally speaking, there are two types of self-talk: motivational self-talk and instructional self-talk. The workbook that you received provides information on using motivational self-talk. Motivational self-talk can be used for increasing your confidence (e.g., “You can do this!”), keeping your mood positive (e.g., “Feeling good!”), psyching yourself up (e.g., “Let’s do this!”), and for remaining motivated to continue (e.g., “Keep pushing!”). As the name suggests, instructional self-talk can be used for instructing yourself about what to do. You can use it for directing your attention to things that are important for performing well, such as the route that you are following (e.g., “Keep looking for the turn on the right”), for executing desired technique (e.g., “Maintain your cadence”, “Drive your elbows”), and for implementing a strategy (e.g., “My pace feels good– Stay at this pace”).

During endurance events like the T60, you might find it helpful to concentrate on performance-relevant cues, such as your running pace, rhythm, or form, or the map and route landmarks for navigation. Concentrating on these performance-relevant cues might become more difficult as the event progresses, as you become more physically and mentally tired. Being able to concentrate on performance-relevant cues could also be particularly important during specific moments of the event, such as during difficult sections of navigation. Some athletes use instructional self-talk statements to help them concentrate on the right things. For example, they might say to themselves, “Focus on your rhythm”, “Watch your pace”, “Keep your mind on the map”, or “Keep looking for the turn on the right". They might also use motivational self-talk statements, such as "Stay with it, keep focused", to encourage concentration. Athletes can also use self-talk statements to re-focus after they have lost their concentration and become distracted (e.g., "Re-focus on the map").

As explained in the self-talk workbook, you could practise using self-talk during training runs and endurance events. The concentration grid may also offer a tool for practising using self-talk. Specifically, you could use self-talk statements to help you concentrate while searching for numbers on the grid, by using statements such as "Stay focused", "Keep concentrating", "You're doing well, keep going", "Number 10 is next", or "Looking for 10". You could also use self-talk to execute a particular strategy that you think could be helpful (e.g., "Focus on the first digit", "Search line by line"). Further, you could practise re-focusing when you become distracted (e.g., "Re-focus on the numbers", "Let's get back on it and find number 10"). As self-talk could be particularly helpful during endurance events when there are distractions or when you are mentally tired, you might find it helpful to practise using self-talk with the concentration grid in distracting environments (e.g., loud, busy rooms) or when you are mentally tired (e.g., after work). As an alternative to the concentration grid, you could practise self-talk during other tasks that require your concentration, such as computer games or *Sudoku*.

Appendix AA

Intake Interview Protocol (Chapter 5)

Checklist	✓
Overview of the intake. Topics discussed will be:	
• Your involvement in distance running and the T60.	
• Your expectations for the T60.	
• What sport psychology is and your experiences with it.	
• Introduction to the workbook.	
• Introduction to the scales completed during the T60.	
Could you tell me how you became involved in distance running? Notes:	
What is your <u>main reason</u> for still doing distance running? Notes:	
Why did you decide to take part in the T60 Night Race? Notes:	
Do you know anyone else who is taking part in the T60 Night Race? Notes:	
What are your expectations for your performance in the T60? Notes:	

What finishing position (Top X %) would you like to achieve? Notes:	
What finishing time would you like to achieve? Notes:	
Do you have any additional goals for the T60? Notes:	
Introduce sport psychology:	
• Psychology is part of every sport (e.g., remaining motivated, concentrating on the right things during performance).	
• Mental training is one part of sport psychology. To me, mental training is about choosing to purposely work on mental aspects of performance and not leaving them to chance. A psychologist can provide guidance on how to do this.	
Do you have any experience with sport psychology? Ask for specific details. • How long ago were these experiences? • How long did this experience last (e.g., how many sessions over how long)? • Specifically, what was this athlete's experience? Notes:	
Do you use any psychological techniques / strategies / tricks when you participate in a running event like the T60? Notes:	

I have asked all of the questions that I would like to ask. Next, I am going to email you a workbook.	
• This workbook describes a psychological strategy, and it includes exercises for you to complete.	
• I would like you to practise the strategy that is described in the workbook for two weeks.	
• Not all participants will receive the same workbook. Please do not tell any other T60 participants anything about the strategy you are learning about.	
• If they know someone who is taking part, specifically ask them not to tell this person about the strategy.	
Do you have any questions at this point? Notes:	
If you have any questions about the workbook, you can email me.	
Introduce the scales completed during the T60	
• Did they read the information sheet I sent them?	
• You will be asked to rate your perceived exertion, exercise-induced pain, and injury-related pain on each of the maps using a marker pen.	
• Explain the difference between perceived exertion, exercise-induced pain, and injury-related pain.	
• These experiences are rated on scales. To reduce inconvenience on the day of T60, you are encouraged to familiarise yourself with these scales.	
• Encourage them to familiarise their self with the content of the information booklet before a run.	
• Encourage them to print off the final page of the information sheet and record RPE and pain during one or more run.	
• Any questions?	
Thank them for their time and commitment to the study so far.	
Duration of intake:	

University of Kent

Self-talk Workbook

Alister McCormick

Introduction

This workbook provides an introduction to self-talk, which is a strategy that you can use while you are training or participating in an endurance event like the T60 Night Race. This workbook introduces self-talk, and it includes exercises that are designed to help you to identify self-talk statements. It is important that you practise using self-talk during training sessions before using it during an event like the T60.

Self-talk

When you are exercising, it is common to repeat certain words or phrases to yourself silently (in your head) or out loud. These words and phrases are called "self-talk" statements. Many athletes are unaware of the content of their thoughts, but this "internal dialogue" can influence how you feel and how you perform. This workbook will help you to identify constructive self-talk statements that you can practise in training and use in endurance events.

Step 1 – Monitor your thoughts during one run

Listen to your thoughts during one run, and notice if any of your self-talk influenced how you felt. Answer the following questions as soon as you can after the run.

1. In the left-hand column of the below table, write down some of the self-talk statements that you said to yourself during the run. Do not feel that you must enter a self-talk statement for each box; simply list as many as you can remember.

Self-talk statement	Did this statement have a positive, negative, or no effect on how you felt?	Please pick up to four statements that had the most beneficial effects
1.	Positive	Picked
2.	Negative	Not picked
3.	No effect	Not picked
4.	No effect	Not picked
5.	No effect	Not picked
6.	No effect	Not picked
7.	No effect	Not picked
8.	No effect	Not picked
9.	No effect	Not picked
10.	No effect	Not picked

2. Some self-talk statements have a positive effect on how you feel, and others have no effect or even a negative effect. Use the dropdown box in the middle column of each row to rate the effect that each statement had on how you felt.

3. Use the dropdown box in the right-hand column of each row to pick up to four statements that had the most beneficial effects. An example is shown below:

"Keep going"	Positive effect	Picked
"I've had enough"	No effect	Not picked

Step 2 – Read examples of motivational statements

Compare your selected statements to the statements listed below:

- It's time to go to work
- This is what you've been training for
- You're ready and totally prepared
- You've worked hard for this
- This will be your best performance ever
- Today is your day
- This is your time to shine
- You're going to dominate today
- You respect all, but fear none
- You're in the best shape of your life
- Let's go, let's do it
- You're a winner
- Feeling good
- You can do it
- I can do this
- You're doing well
- Push it
- Keep going, be strong
- Dig deep
- You can go all the way
- You're in control
- Hang on in there
- Drive forward
- You're a force today
- You run the show
- Come on, keep pushing
- Give it your all
- Leave nothing behind
- Come on! Come on!
- Smash this!
- Keep it going!
- Keep pushing! You can handle this!

Step 3 – Choose four self-talk statements

Using the **two lists** on the previous two pages (i.e., your list and our list), pick **four statements** that you think would be **most beneficial** during the T60 Night Race.

When choosing these statements, pick at least one statement for each of the three stages of the run (earlier, middle, and later stages). I suggest choosing two statements for the stage of the race where you think self-talk will be most valuable.

Earlier Stages
•
•
Middle Stages
•
•
Later Stages
•
•

Countering unhelpful thoughts

When you are running for a long time, it is likely that you will use unhelpful self-talk statements that encourage you to "give up" and put in less effort. You can use a countering technique to keep going.

Every time you hear yourself repeating a negative statement, you should recognise it and respond with a motivational statement. For example, if you said to yourself, "This hurts, I want to give up" at the halfway point of a long-distance run, you could respond with the phrase, "Come on, I know I can do this!"

Using self-talk during critical moments

You could use self-talk statements during critical moments of the T60. For example, self-talk might be valuable in the following situations:

- You are hitting the wall
- You feel exceptionally sleepy
- You've lost 10 minutes by getting lost
- Continuing running suddenly seems really difficult
- You are falling behind your time targets
- Something goes wrong (e.g., nutritional strategy)

Please list one or more statements that could be valuable in such situations.

•
•

Step 4 – Practise your chosen statements

On page 5, you chose four statements. It is important that you practise using these statements. Self-talk is a skill that is developed through practice, like a physical skill. By practising self-talk, it becomes more automatic and natural.

Until the date of the T60, we would like you to use your statements during each running training session or long-distance event (e.g., long-distance runs, race-pace runs). You could say the statements silently in your head or you could say them out loud. To help you make the most of these statements, there are four things to remember:

1. Remind yourself of your four chosen statements before each training session or running event, and think about when they might be helpful.
2. During the run, use your statements whenever you think they might be helpful. I suggest using your statements often.
3. You can use your statements to counter unconstructive thoughts.
4. You can use your statements during critical moments of the run.

You could print off the following page (page 8) to remind yourself of your statements before each run, including the T60.

Step 5 – Completing self-talk logs

Please complete self-talk training logs (page 9 onwards) after four runs. We would like you to provide us with these four logs. Each log will take approximately five minutes to complete. Please email the four completed logs to Alister (AM801@kent.ac.uk). Alternatively, you could bring printed versions to the T60.

If you found a particular statement unhelpful, consider replacing it and practising a different statement instead during your next run. Simply complete the next log using the new statement instead of the old one. Similarly, if you wish to alter the wording, then simply complete the next log using the adjusted wording.

-------------- ✂ --

My four chosen self-talk statements are:

1.
2.
3.
4.

Remember:

1. Use these statements often.
2. Use these and similar statements to counter unproductive thoughts.
3. Use these and similar statements during critical moments (e.g., something goes wrong).
4. When might these statements be helpful during the run?

-------------- ✂ --

My four chosen self-talk statements are:

1.
2.
3.
4.

Remember:

1. Use these statements often.
2. Use these and similar statements to counter unproductive thoughts.
3. Use these and similar statements during critical moments (e.g., something goes wrong).
4. When might these statements be helpful during the run?

-------------- ✂ --

My four chosen self-talk statements are:

1.
2.
3.
4.

Remember:

1. Use these statements often.
2. Use these and similar statements to counter unproductive thoughts.
3. Use these and similar statements during critical moments (e.g., something goes wrong).
4. When might these statements be helpful during the run?

-------------- ✂ --

My four chosen self-talk statements are:

1.
2.
3.
4.

Remember:

1. Use these statements often.
2. Use these and similar statements to counter unproductive thoughts.
3. Use these and similar statements during critical moments (e.g., something goes wrong).
4. When might these statements be helpful during the run?

-------------- ✂ --

Self-talk Log 1

Participant ID: T60-__ __ __	Date of run:
Please provide brief information on this run (e.g., distance, duration, pace):	
Instructions: Having reviewed a list of possible self-talk statements, you picked four statements that you think will be helpful during the T60 Night Race. The self-talk statements that you picked are listed in the spaces provided on page 5. Please answer the following questions about your use of these statements during your most recent training session or running event.	

Generally speaking, to what extent did you remember to use the self-talk statements during the run?

0 1 2 3 4 5 6 7 8 9 10

Not at all **Greatly**

Generally speaking, to what extent were you able to use the self-talk statements during the run?

0 1 2 3 4 5 6 7 8 9 10

Not at all **Greatly**

Generally speaking, to what extent were you comfortable using self-talk statements during the run?

0	1	2	3	4	5	6	7	8	9	10

Not at all **Very Comfortable**

To what extent did you use self-talk to counter negative statements that you were saying to yourself?

0	1	2	3	4	5	6	7	8	9	10

Never **All the time**

Did you use self-talk during critical moments of the run? (✓)

Yes	
There was not a critical moment	
No	

Please list the self-talk statements that you used during this run:

Please list the self-talk statements that were particularly helpful during this run:

Please provide brief details on how these statements helped (e.g., when did they help, what did they help you with):

Please list the self-talk statements that were unhelpful during this run:

If you found a particular statement unhelpful, consider replacing it and practising a different statement instead during your next run. Simply complete the next log using the new statement instead of the old one. Similarly, if you wish to alter the wording, then simply complete the next log using the adjusted wording.

Please list the self-talk statements that you intend to use during your next run:

Appendix AC

Concentration Workbook and Sample Log (Chapter 5)

Concentration Workbook

Alister McCormick

Concentration

Concentration is important in many sports, including endurance sports. Athletes need to pay attention to the factors that are relevant to their performance, and they need to ignore irrelevant distractions. Athletes have been encouraged to develop their concentration by practising a concentration grid, like the one in this workbook. This workbook provides an introduction to the concentration grid, and it includes exercises for you to practise.

What is a concentration grid?

A concentration grid is a box that contains 100 randomly-distributed numbers. It contains all of the numbers from (and including) 0 to 99.

How do I use a concentration grid?

You begin by finding number 00 and circling it. You then find number 01 and circle it. You continue to find and circle the next numbers (02, 03, 04, and so on) until you run out of time. The challenge is to circle as many numbers as you can within one minute. If you do not have a timer, you could use the following internet-based countdown timer:

http://www.online-stopwatch.com/countdown-timer/

It is important to practise using the concentration grid in noisy locations as well as quiet locations, so that you can practise concentrating with and without distractions.

There is an example concentration grid on the next page of the workbook. Practise completing this in a quiet environment. How many numbers did you circle within one minute?

Note: Concentration grids can be printed, or you could view the whole grid on your computer screen using approximately 75% zoom.

38	28	51	09	71	16	72	82	63	04
10	32	44	62	21	97	18	40	90	52
25	85	57	46	66	35	78	96	11	69
74	03	75	93	00	56	22	67	49	20
43	13	23	33	79	95	76	05	59	45
65	86	50	19	41	07	37	83	29	61
58	02	34	77	27	55	92	48	01	89
15	47	73	87	39	68	12	53	84	70
24	64	81	06	91	60	88	30	98	14
99	31	42	94	17	54	80	26	36	08

Practise using the concentration grid

Now that you have learned to use the concentration grid, it is important that you practise using it. Concentration is a skill that is developed through practice, like a physical skill.

Between now and the T60 Night Race, we would like you to complete at least two concentration grids each day, on as many days as possible. Practise once in a quiet environment, and practise once in a distracting environment (e.g., with the TV switched on).

We suggest completing a concentration grid within an hour of starting a training session that is relevant to the T60 (e.g., long-distance run, race-pace run). If you intend to complete a training run, please practise the concentration grid before you set off. If you are not training on a particular day, you can still practise the concentration grid.

Concentration grids are included at the end of this workbook. Rather than starting each concentration grid by circling 00, we have stated the first number that you should circle at the top of each concentration grid. In other words, if it reads "Start on number 39", you would start by circling 39, 40, 41, and so on. If you reach number 99, you should then search for numbers 00, 01, 02, and so on.

Please complete concentration grid logs (pages 5 to 8) on at least four days, once you have completed the day's two (or more) concentration grids. Each log will take approximately five minutes to complete. We would like you to provide us with these four logs. On days when you do not complete a log, please make a note of how many numbers you circled in the quiet and distracting environments.

Please email the four completed logs to Alister (AM801@kent.ac.uk). Alternatively, you could bring printed versions to the T60.

Concentration Grid Log 1

Participant ID: T60-__ __ __	Date of concentration grid:
Did you complete the grid before a run?	Yes / No
Please provide brief information on this run (e.g., distance, duration, pace):	
Instructions: Between now and the T60 Night Race, we would like you to complete at least two concentration grids each day, on as many days as possible. Practise once in a quiet environment, and practise once in a distracting environment (e.g., with the TV switched on). If you intend to complete a training run, please practise the concentration grid during the hour before you set off. If you are not training on a particular day, you can still practise the concentration grid. You will find concentration grids at the end of the workbook. Each concentration grid states the first number that you should circle. Please answer the following questions about completing the concentration grid on the most-recent occasion.	

Please describe the environment that you completed the concentration grid in (e.g., quiet, loud, café, at work, at home, family present, television / radio on):

Quiet environment	Distracting environment

Please describe how you felt while you were completing the concentration grid:

	Quiet environment	Distracting environment
How many numbers did you circle in one minute?		
What is your best performance to date?		