Title of the manuscript: What does it take to complete the Cape Epic?

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Abstract

This study aimed to describe the racing and training demands of the Cape Epic. Six male mountain bike riders (age: 39±7 years, height: 181±3 cm, body mass: 78.7±8.1 kg) trained for 4.5 months and took part in the Cape Epic. Training and racing data (prologue, stage 1, and 2) were analysed, and riders were tested in the laboratory on three distinct occasions for maximal oxygen uptake ($\dot{V}O_{2max}$), maximal work rate ($\dot{W}_{max}$), and power output associated with the respiratory compensation point (RCP_{PO}). Statistical significance was set at $P \leq 0.05$. With race durations of 1.5±0.2, 6.5±1.2, and 6.4±1.4 hours for respectively prologue, stage 1, and 2, normalised power was higher in prologue (3.73±0.72 $W \cdot kg^{-1}$) compared with stages 1 (3.06±0.59 $W \cdot kg^{-1}$, $P<0.001$), and 2 (2.94±0.69 $W \cdot kg^{-1}$, $P<0.001$). Riders spent more time in power zones 1 and 2 (as %RCP_{PO}), and less time in zones 4 and 5, during stage 2 compared with prologue (all zones $P \leq 0.028$). Despite no changes in $\dot{V}O_{2max}$ or $\dot{W}_{max}$, RCP_{PO} increased from mid-training (3.89±0.61 $W \cdot kg^{-1}$) to pre-race testing (4.08±0.64 $W \cdot kg^{-1}$, $P=0.048$). No differences were found between base and build training phases for time in power zones. In conclusion, the Cape Epic requires an ability to sustain high submaximal power outputs for several hours as well as an ability to repeat high-intensity efforts throughout the race. A well-balanced programme, incorporating a pyramidal intensity distribution, may be utilised as a starting point for the design of optimal training approaches.

Keywords

MTB stage race; physiological demands; off-road cycling; intensity distribution; periodization; case study.

INTRODUCTION

The Cape Epic is an 8-day mountain bike (MTB) stage race held in South Africa yearly since 2006. The Cape Epic is raced in pairs with riders required to cover a distance of approximately 650 km and an elevation gain of approximately 15,000 m. It typically starts with a short prologue (approximately 25 km), which is followed by seven longer stages (> 90 km) on consecutive days, suggesting athletes require ultra-endurance (defined as exercise duration > 6 h (29)) capabilities to maintain high power outputs for extended periods. Despite ever-growing popularity, research about MTB stage races, and the Cape Epic in particular, is scarce (7, 22, 27).

MTB races usually include long and steep ascents requiring high power outputs, as well as technical descents, when riders spend considerable time coasting (10). As such, power output varies substantially throughout a race (i.e. stochastic) (8, 9, 24), meaning these events are highly demanding for both aerobic and anaerobic energy systems (8-10, 24, 27). Despite this complexity in energetic demand, the only study that has specifically investigated the demands of MTB stage races is based on the analysis of heart rate profiles (27). In this study, Wirnitzer and Kornexl (27) found that on average riders spent 36% of the total racing time at heart rates equivalent to blood lactate concentrations > 4 $mmol \cdot L^{-1}$. However, the measurement of heart rate is well known to be influenced by several confounding factors (e.g. weather, hydration status, and cardiovascular drift), whereas power output represents racing demands more objectively (12). Accordingly, obtaining power output recordings from riders taking part in MTB stage races is essential to understand these events, ultimately informing the design of effective training plans.

One aspect of endurance training that has been considered important for maximizing performance is training intensity distribution throughout the season (2, 23, 25). It has been shown that cyclists usually opt for a pyramidal intensity distribution (16, 18, 21, 28) (i.e. the higher the intensity is, the less training is performed at that intensity), while some other endurance athletes prefer a polarized approach (i.e. training is mostly performed at either end of the intensity spectrum) (2, 23, 25). Notably, training intensity distribution has yet to be shown in mountain biking, although this may provide valuable information on how to prepare for MTB races.

The first aim of this study was to describe the racing demands of the Cape Epic from the perspective of both power output and heart rate. The second aim was to describe training demands during the months leading to the event. We hypothesized that the Cape Epic would require both high-intensity exercise and ultra-endurance capabilities, which may not be evident by analysing heart rates only. We also hypothesized that training-intensity distribution would be consistent with previous cycling studies (i.e. pyramidal).

METHODS

Experimental Approach to the Problem

A within-subjects design was used to describe the training and racing demands of the Cape Epic. This study lasted 4.5 months and finished with the Cape Epic at the end of March (Figure 1). Riders attended the laboratory for testing at the end of October, mid-January, and at the beginning of March. Testing consisted of a dual-energy x-ray absorptiometry (DXA) scan, for the assessment of body composition, and an incremental test, for the assessment of $\dot{V}O_{2max}$, $\dot{W}_{max}$, as well as power output (RCP_{PO}) and heart rate (RCP_{HR}) associated with the respiratory compensation point (RCP). Riders were advised to avoid strenuous exercise during the 24 h preceding laboratory visits, to keep energy and fluid levels adequate, and to prepare as they would for competition. They did not consume tobacco, alcohol or caffeine on testing days.

Figure 1 here

Subjects

Six male mountain bike riders took part in this study (convenience sample; age: 39 ± 7 years, height: 181 ± 3 cm, body mass: 78.7 ± 8.1 kg), who were classified as professional [1], well-trained [1], trained [2], and recreationally-trained [2] according with their maximal oxygen uptake ($\dot{V}O_{2max}$) and maximal work rate in the incremental test ($\dot{W}_{max}$) (5). Tartu University's ethics committee approved the study in compliance with the Declaration of Helsinki. All participants provided written informed consent.

DXA scan

Participants were scanned in supine position wearing light clothing (Discovery, Hologic, Marlborough, MA, USA). The medium scan mode was selected, and data were analysed using the extended analysis option (v3.6, proprietary software).

Incremental test

Riders performed an incremental test to volitional exhaustion on their own bicycle, mounted on a cycle ergometer (Cyclus 2, RBM Elektronik-Automation, Leipzig, Germany) considered valid and reliable (20). After a 5-min warm-up at 100 W, work rate was increased by 50 W every 2.5 min. If the last stage was not completed, $\dot{W}_{max}$ was calculated proportionally (13). Breath-by-breath respiratory gas exchanges were monitored throughout the tests with data being stored in 10-s intervals (MetaMax 3B, Cortex Biophysik, Leipzig, Germany). The analyser was calibrated prior to every test according with the manufacturer's guidelines. $\dot{V}O_{2max}$ was determined as the highest 30-s oxygen uptake average. RCP was identified based on a) an increase of both ventilatory equivalent for oxygen and ventilatory equivalent for carbon dioxide, b) a decrease of end-tidal partial pressure of carbon dioxide, and c) a second slope increase on the curve between minute ventilation and work rate (26). Two physiologists analysed all data separately and a third one was involved if there was no consensus.

Training programme

Riders followed a programme devised by a single coach based on three weeks of training load increments followed by a recovery week, if necessary. Testing was always performed at the end of a recovery week. The main goal during base was to establish a high RCP_{PO}. During build, the main goal was to increase the amount of work above RCP_{PO} and simulate MTB stage race conditions. During taper, the main goal was to make riders race-ready by providing them with a low training load to permit recovery.

As participants were not professional athletes, cross-training (mostly cross-country skiing and hiking) was frequently employed as a strategy to maintain fitness during times of minimal availability for cycling training. Even though cross-training represented approximately 5% of the total training volume, it is not reported in this study because these data were not systematically recorded by riders.

Race

The 2016 Cape Epic consisted of a prologue and seven stages on consecutive days (Table 1). Athletes were divided into pairs (i.e. teams) according with their laboratory testing results. Race rules dictate that members of the same team must ride together at all times, with a maximal time difference of two minutes throughout the race.

Table 1 here

Data recording

Power output was measured at 1 Hz by crank power meters (Rotor Bike Components, Madrid, Spain), and heart rate was recorded by ANT+ belts (Garmin, Olathe, KS, USA). Personal-use power meters have been generally considered valid and reliable (14). Riders were instructed to perform the zero offset procedure prior to every training session or race stage. All data were logged by a cycle computer (Garmin, Olathe, KS, USA), and subsequently stored and analysed using dedicated software (WKO 4.0, Peaksware, Boulder, CO, USA).

Data analysis

In a previous study, the average power output in a field-based, 20-min time trial was found to coincide reasonably with RCP_{PO} (19). Accordingly, RCP_{PO} and RCP_{HR} were used to determine five intensity zones based on power output and heart rate, respectively (Table 2) (1). Subsequently, time spent in power and heart rate zones as a percentage of total time were calculated for base and build phases, and for each race stage. Training zones were adjusted after every laboratory testing to ensure accuracy. In addition, time spent in eleven 0.75 $W \cdot kg^{-1}$ power bands (i.e. ranging from < 0.75 to > 7.50 $W \cdot kg^{-1}$) as a percentage of total time was calculated for each training phase, and for each race stage (15).

Table 2 here

Normalised power was calculated for each training session and race stage as follows: a) second-by-second power output data were converted to 30-s rolling averages, b) averages were raised to the fourth power, c) resulting values were averaged, and d) fourth root was taken to generate a single number. In theory, normalised power represents the "real" intensity had power output been maintained constant throughout the exercise (1). Training stress score was calculated for each training session and race stage through the following equation (1):

$$TSS = [(t \times NP \times IF) / (RCP_{PO} \times 3600)] \times 100 \quad (1)$$

where TSS is training stress score, t is the duration of the exercise session (s), NP is the normalised power of the exercise session (W), and IF is the ratio between normalised power and RCP_{PO}.

Due to technical problems with power meters, and non-compliance with training recording instructions in the case of one participant, fewer data were acquired than had been anticipated. Hence, training data from five riders only are presented (with 6.3 ± 2.2 % of their data missing). A combination of power meter malfunctions and severe crashes that resulted in race dropouts also precluded that data of stages 3, 4, 5, and 7 could be summarised. Accordingly, racing data from all six riders are presented for prologue, stage 1, and stage 2, and from four riders for Stage 6. However, stage 6 data were not included in the statistical analysis, except for race duration, in which each team was represented by a single completion time.

Statistical analysis

Data were assessed for normality using Shapiro-Wilk's test and normal quantile plots (4), with subsequent analyses chosen accordingly. The reader is referred to Chan (3) for a tutorial on parametric and non-parametric tests.

One-way analysis of variance was performed to investigate differences between stages in mean power output (including zeros), normalised power, power output variability (as a coefficient of variation), coasting time (as a percentage of moving time), race duration, and training stress score. Bonferroni's pairwise comparisons were used to identify where significant differences existed within the data. Friedman's test was used to analyse differences between stages in time spent in power and heart rate zones, as well as in time spent in power bands. Dunn's pairwise comparisons were used to identify where significant differences existed within the data.

One-way analysis of variance and Bonferroni's pairwise comparisons were chosen to investigate differences during the season in body mass, $\dot{V}O_{2max}$, $\dot{W}_{max}$, and RCP_{PO}.

Differences in training volume, mean power output, and power output variability between base and build training phases were investigated via dependent sample t-test. To investigate differences between training phases in time spent in power and heart rate zones, as well as in time spent in power bands, a Wilcoxon test was used. Friedman's test and Dunn's pairwise comparisons were chosen to investigate differences in weekly training duration and weekly training stress score.

Results are presented as mean ± SD, and Cohen's d standardised effect sizes or eta-squared (η^2) are reported when appropriated. Data analysis was performed using dedicated software (Prism 8, GraphPad, San Diego, USA). Statistical significance was set at $P \leq 0.05$.

RESULTS

Racing parameters

There was an effect of stage on mean power output (prologue: 3.08 ± 0.74 $W \cdot kg^{-1}$, stage 1: 2.43 ± 0.66 $W \cdot kg^{-1}$, stage 2: 2.22 ± 0.70 $W \cdot kg^{-1}$, stage 6: 2.75 ± 1.06 $W \cdot kg^{-1}$; $P < 0.001$, $\eta^2 = 0.95$), normalised power ($P < 0.001$, $\eta^2 = 0.92$ – Figure 2A), power output variability (prologue: 64.4 ± 9.6 %, stage 1: 71.4 ± 11.8 %, stage 2: 78.7 ± 13.6 %, stage 6: 72.3 ± 15.3 %; $P < 0.001$, $\eta^2 = 0.88$), coasting time ($P < 0.001$, $\eta^2 = 0.93$ – Figure 2B), race duration ($P = 0.016$, $\eta^2 = 0.96$ – Figure 2C), and training stress score ($P < 0.001$, $\eta^2 = 0.91$ – Figure 2D). While mean power output and normalised power were higher in prologue compared with stages 1 (both $P < 0.001$), and 2 (both $P < 0.001$), power output variability and coasting time were lower in prologue compared with stages 1 (both $P \leq 0.022$), and 2 (both $P \leq 0.004$). Besides, power output variability and coasting time in stage 1 were lower than in stage 2 (both $P \leq 0.016$). Race duration was shorter in stage 6 compared with stages 1 ($P = 0.018$), and 2 ($P = 0.043$), and training stress score was lower in prologue compared with stages 1 ($P < 0.001$), and 2 ($P < 0.001$).

Figure 2 here

There was an effect of stage on time spent in power zones 1 ($P < 0.001$), 2 ($P = 0.006$), 4 ($P = 0.029$), and 5 ($P = 0.002$), but not for zone 3 ($P = 0.25$). Riders spent more time in zones 1 and 2, and less time in zones 4 and 5, during stage 2 compared with prologue (all zones $P \leq 0.028$ – Figure 3A). There was an effect of stage on time spent in heart rate zones 1 ($P = 0.006$), 2 ($P = 0.002$), and 4 ($P = 0.002$), but not for zones 3 ($P = 0.25$), and 5 ($P = 0.333$). Riders spent more time in zones 1 and 2, and less time in zone 4, during stage 2 compared with prologue (all zones $P \leq 0.012$ – Figure 3B). An effect of stage was also found on time spent in power bands "< 0.75", "1.51-2.25", "4.51-5.25", "5.26-6.00", "6.01-6.75", "6.76-7.50", and "> 7.50" (all bands $P \leq 0.006$), but not for the others (all bands $P \geq 0.052$). Riders spent more time in bands "< 0.75" and "1.51-2.25", and less time in bands "4.51-5.25", "5.26-6.00", "6.01-6.75", "6.76-7.50", and "> 7.50", during stage 2 compared with prologue (all bands $P \leq 0.012$ – Figure 3C).

Figure 3 here

Laboratory parameters

Despite no changes in body mass (October: 78.7 ± 8.1 kg, January: 79.2 ± 8.2 kg, March: 78.8 ± 7.8 kg; $P = 0.77$, $\eta^2 = 0.03$), absolute $\dot{V}O_{2max}$ ($P = 0.10$, $\eta^2 = 0.44$ – Figure 4A), relative

$\dot{V}O_{2max}$ (P = 0.07, η^2 = 0.51 – Figure 4B), absolute $\dot{W}_{max}$ (P = 0.42, η^2 = 0.14 – Figure 4C), or relative $\dot{W}_{max}$ (P = 0.45, η^2 = 0.13 – Figure 4D), both absolute RCP_{PO} (P = 0.009, η^2 = 0.66 – Figure 4E) and relative RCP_{PO} (P = 0.020, η^2 = 0.58 – Figure 4F) improved during the training period. While absolute RCP_{PO} was higher in March compared with both October (P = 0.038) and January (P = 0.032), relative RCP_{PO} was higher in March compared with January only (P = 0.048).

Figure 4 here

Training parameters

Riders trained 164 ± 30 h of cycling in total (base: 75 ± 16 h, build: 89 ± 15 h; P = 0.023, d = 1.61), at mean power outputs of 2.58 ± 0.59 W·kg^{-1} during base, and of 2.61 ± 0.48 W·kg^{-1} during build (P = 0.826, d = 0.01). Even though build was characterised by a higher power output variability compared with base (base: 42.6 ± 5.6 %, build: 58.0 ± 3.4 %; P = 0.005, d = 2.55), no differences were found between base and build for either time spent in power (all zones P ≥ 0.31 – Figure 5A) or heart rate zones (all zones P ≥ 0.31 – Figure 5B). Similarly, there was no difference between base and build for time spent in power bands (all bands P ≥ 0.06 – Figure 5C). There was an effect of week number on both training duration (P = 0.003 – Figure 5D) and training stress score (P < 0.001 – Figure 5E). While training duration in week 12 was shorter than in weeks 3 (P = 0.040), 10 (P = 0.040), and 15 (P = 0.05), training stress score was lower in week 12 compared with weeks 10 (P = 0.05), and 11 (P = 0.040). Besides, training stress score in week 19 was lower than in week 11 (P = 0.044).

Figure 5 here

DISCUSSION

This is the first study to report power output from riders taking part in a MTB stage race. Confirming our first hypothesis, the data revealed that a mix of high-intensity exercise and ultra-endurance capabilities are required to complete the Cape Epic. If we take the shortest and longest stages, for instance, normalised power was approximately 91% of RCP_{PO} for the 1.5-h prologue and approximately 75% of RCP_{PO} for the 6.5-h stage 1. Moreover, approximately 24% and 12% of the total race time, for prologue and stage 1, respectively, was spent at power outputs above 4.51 $W\cdot kg^{-1}$ (i.e. above RCP_{PO}). Confirming our second hypothesis, the training-intensity distribution of Cape Epic riders was pyramidal, with no major shifts between base and build phases.

In a previous study, Engelbrecht and Terblanche (7) investigated the physiological attributes required to complete the Cape Epic. Within the eight weeks preceding the race, twenty-four recreationally-trained riders performed an incremental test to exhaustion associated with measures of respiratory gas exchanges and blood lactate concentration. Interestingly, the power output associated with 4-$mmol\cdot L^{-1}$ lactate concentration (4-$mmol\cdot L^{-1}{}_{PO}$) was the strongest predictor of overall racing time (r = -0.80), whereas $\dot{V}O_{2max}$ did not correlate (r = -0.14) (7). The fact that 4-$mmol\cdot L^{-1}{}_{PO}$ was the strongest performance predictor is likely connected with the extent to which, in our study, time spent in zone 3 (76% – 90%RCP_{PO}), or in bands “2.26-3.00”, “3.01-3.75”, and “3.76-4.50” were consistent across all stages (see Figure 3). Even though 4-$mmol\cdot L^{-1}{}_{PO}$ may not coincide with RCP_{PO}, both indexes are believed to reflect the ability to tolerate high work rates for prolonged periods of exercise, setting the upper limit for the isocapnic buffering phase (17). In contrast, our results suggest that the secondary role of a high $\dot{V}O_{2max}$ may not be reflected in correlational analyses as employed by Engelbrecht and Terblanche (7). The high prevalence of high-intensity efforts interspersed with coasting or low-intensity efforts (see Figures 2 and 3), and the coefficient of variation for power output always superior to 60% (i.e. similar to XCO races (8, 10, 24)), may provide indirect evidence of an association between $\dot{V}O_{2max}$ and Cape Epic performance. In particular, the polarized power output distribution we observed during prologue, with time spent in zone 5 (≥ 106%RCP_{PO}) approximating 27%, reveals its stark similarity with the demands of cross-country Olympic (XCO) MTB races (8, 9, 24)—in which the role of a high $\dot{V}O_{2max}$ has been more firmly established (10). This might help to explain why some of the best elite XCO riders have also excelled in the Cape Epic (e.g. Nino Schurter and Henrique Avancini). Further studies are required to test this hypothesis.

However, when time spent in heart rate zones is considered, a different picture emerges. At least 50% of each stage was spent in zones 2 and 3, with minimal time spent in zones 1 and 5. Our findings therefore contrast with those of Wirnitzer and Kornexl (27), in which riders spent 36% of the total racing time at heart rates equivalent to blood lactate concentrations > 4 mmol·L^{-1} in another 8-day stage race (i.e. Transalp Challenge). By assuming that the 4-mmol·L^{-1} intensity would be placed somewhere close to the lower end of zone 4 (17), only prologue heart rate distribution would match Wirnitzer and Kornexl's findings (27). Indeed, Stapelfeldt et al. (24) and Jeukendrup and Van Diemen (12) have demonstrated that heart rate may fail to track changes in power output during XCO and road races, respectively, which is in agreement with our conflicting heart rate- and power-based intensity distributions.

Heart rate is considered to be an internal bodily response, whereas power output is an external response; the latter representing racing workload more objectively (12).

Interestingly, during the training period preceding the Cape Epic, riders improved RCP_{PO}, but not $\dot{V}O_{2max}$ or $\dot{W}_{max}$. This contrasts with data from twelve well-trained XCO riders whose seasonal improvements in $\dot{V}O_{2max}$, $\dot{W}_{max}$, and 4-mmol·$L^{-1}{}_{PO}$ were evident (10). While our small sample size may account for the lack of $\dot{V}O_{2max}$ and $\dot{W}_{max}$ changes, it has been shown that XCO performance correlates only with RCP_{PO} in a group of professional riders homogeneous for $\dot{V}O_{2max}$ (11). It is therefore conceivable that RCP_{PO} could be more sensitive to the performance gains associated with MTB training compared with $\dot{V}O_{2max}$ or $\dot{W}_{max}$. We therefore recommend that laboratory-based performance monitoring prior to MTB stage races should be focused on RCP_{PO}.

Consistent with the training of road cyclists (16, 18, 21, 28), Cape Epic riders adopted a pyramidal intensity distribution (see Figure 5A). It is interesting, however, that unlike in previous studies with either cyclists (16, 28) or other endurance athletes (23, 25), a shift towards a more polarized approach from base to build was not detected. The only noticeable pattern was a higher variability in weekly training duration and weekly training stress score during build, primarily driven by a training camp in weeks 10 and 11. Collectively, these data indicate that a pyramidal training programme with approximately 9 h of cycling per week, and no major deviations in intensity distribution within the season, may be an effective approach to complete MTB stage races.

This study is not without limitations. Due to its nature, getting a large sample size and complete racing data was logistically challenging, restricting the generalizability of our results. For the same reason, we may have failed to detect some important training and racing trends. As a single coach prescribed the training programme, and given the absence of $\dot{V}O_{2max}$ and $\dot{W}_{max}$ changes, there likely are other effective training strategies. Moreover, power and heart rate zones were derived from RCP, rather than the so-called functional threshold power as originally proposed by Allen and Coggan (1), potentially biasing time in zones slightly. Finally, the validity of normalised power and training stress score as exercise-demand indicators remain to be determined, despite their widespread use by coaches and scientists.

In conclusion, the Cape Epic requires primarily an ability to sustain a high submaximal power output for several hours, and to a lesser extent, an ability to perform repeated high-intensity efforts throughout the race. However, heart rate may not be as sensitive as power output to assess the demands of MTB stage races. A well-balanced programme, incorporating a pyramidal intensity distribution, may be utilised as a starting point for the design of optimal individual training approaches.

PRACTICAL APPLICATIONS

Although not a case study per se, the present investigation may be viewed as such. Readers are therefore encouraged to inspect figures in detail and take advantage of the presentation of individual data points (6). As per the specificity principle (29), our racing data suggest that training programmes for MTB stage races should include long sessions (> 6 h) and encompass the entire spectrum of exercise intensities. A pyramidal intensity distribution, as adopted by our participants, provides not only a strong endurance foundation (i.e. zones 2 and 3) but also high-intensity specificity according with the power output distribution manifested during the race (except for prologue). Given the XCO-type demands of prologue (i.e. polarized power output distribution), high-intensity workouts at $\geq$ 91%RCP_{PO} (i.e. zones 4 and 5) should be emphasised as riders approach their target race. Our participants' normalised power, consistent with the ability to tolerate moderately high work rates for several hours (i.e. zone 3), provides an intensity reference for race simulations and training camps.

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REFERENCES

1. Allen H and Coggan A. *Training and racing with a power meter*. VeloPress, 2010.

2. Bourgois JG, Bourgois G, and Boone J. Perspectives and determinants for training-intensity distribution in elite endurance athletes. *Int J Sports Physiol Perform* 14: 1151-1156, 2019.

3. Chan YH. Biostatistics 102: quantitative data - parametric & non-parametric tests. *Singapore Med J* 44: 391-396, 2003.

4. Curran-Everett D. Explorations in statistics: the assumption of normality. *Adv Physiol Educ* 41: 449-453, 2017.

5. De Pauw K, Roelands B, Cheung SS, de Geus B, Rietjens G, and Meeusen R. Guidelines to classify subject groups in sport-science research. *Int J Sports Physiol Perform* 8: 111-122, 2013.

6. Drummond GB and Vowler SL. Show the data, don't conceal them. *Adv Physiol Educ* 35: 130-132, 2011.

7. Engelbrecht L and Terblanche E. Physiological performance predictors in mountain bike multi-stage races. *J Sports Med Phys Fitness* 58: 951-956, 2018.

8. Granier C, Abbiss CR, Aubry A, Vauchez Y, Dorel S, Hausswirth C, and Le Meur Y. Power output and pacing during international cross-country mountain bike cycling. *Int J Sports Physiol Perform* 13: 1243-1249, 2018.

9. Hays A, Devys S, Bertin D, Marquet LA, and Brisswalter J. Understanding the physiological requirements of the mountain bike cross-country olympic race format. *Front Physiol* 9: 1062, 2018.

10. Impellizzeri FM and Marcora SM. The physiology of mountain biking. *Sports Med* 37: 59-71, 2007.

11. Impellizzeri FM, Marcora SM, Rampinini E, Mognoni P, and Sassi A. Correlations between physiological variables and performance in high level cross country off road cyclists. *Br J Sports Med* 39: 747-751, 2005.

12. Jeukendrup A and VanDiemen A. Heart rate monitoring during training and competition in cyclists. *J Sports Sci* 16 Suppl: S91-99, 1998.

13. Kuipers H, Verstappen FT, Keizer HA, Geurten P, and van Kranenburg G. Variability of aerobic performance in the laboratory and its physiologic correlates. *Int J Sports Med* 6: 197-201, 1985.

14. Maier T, Schmid L, Muller B, Steiner T, and Wehrlin JP. Accuracy of cycling power meters against a mathematical model of treadmill cycling. *Int J Sports Med* 38: 456-461, 2017.

15. Martin DT, McLean B, Trewin C, Lee H, Victor J, and Hahn AG. Physiological characteristics of nationally competitive female road cyclists and demands of competition. *Sports Med* 31: 469-477, 2001.

16. Metcalfe AJ, Menaspa P, Villerius V, Quod M, Peiffer JJ, Govus AD, and Abbiss CR. Within-season distribution of external training and racing workload in professional male road cyclists. *Int J Sports Physiol Perform* 12: S2142-s2146, 2017.

17. Meyer T, Lucía A, Earnest CP, and Kindermann W. A conceptual framework for performance diagnosis and training prescription from submaximal gas exchange parameters -theory and application. *Int J Sports Med* 26 Suppl 1: S38-48, 2005.

18. Nimmerichter A, Eston RG, Bachl N, and Williams C. Longitudinal monitoring of power output and heart rate profiles in elite cyclists. *J Sports Sci* 29: 831-840, 2011.

19. Nimmerichter A, Williams C, Bachl N, and Eston R. Evaluation of a field test to assess performance in elite cyclists. *Int J Sports Med* 31: 160-166, 2010.

20. Rodger SM, Plews DJ, McQuillan J, and Driller MW. Evaluation of the Cyclus ergometer and the Stages power meter against the SRM crankset for measurement of power output in cycling. *J Sci Cycling* 5: 16-22, 2016.

21. Sanders D, Myers T, and Akubat I. Training-intensity distribution in road cyclists: objective versus subjective measures. *Int J Sports Physiol Perform* 12: 1232-1237, 2017.

22. Schenk K, Gatterer H, Ferrari M, Ferrari P, Cascio VL, and Burtscher M. Bike Transalp 2008: liquid intake and its effect on the body's fluid homeostasis in the course of a

multistage, cross-country, MTB marathon race in the central Alps. *Clin J Sport Med* 20: 47-52, 2010.

23. Seiler S. What is best practice for training intensity and duration distribution in endurance athletes? *Int J Sports Physiol Perform* 5: 276-291, 2010.

24. Stapelfeldt B, Schwirtz A, Schumacher YO, and Hillebrecht M. Workload demands in mountain bike racing. *Int J Sports Med* 25: 294-300, 2004.

25. Stöggl TL and Sperlich B. The training intensity distribution among well-trained and elite endurance athletes. *Front Physiol* 6: 295, 2015.

26. Wasserman K, Hansen JE, Sue DY, Stringer WW, Sietsema KE, Sun XG, and Whipp BJ. *Principles of Exercise Testing and Interpretation*. Lippincott Williams & Wilkins, 2012.

27. Wirnitzer KC and Kornexl E. Exercise intensity during an 8-day mountain bike marathon race. *Eur J Appl Physiol* 104: 999-1005, 2008.

28. Zapico AG, Calderon FJ, Benito PJ, Gonzalez CB, Parisi A, Pigozzi F, and Di Salvo V. Evolution of physiological and haematological parameters with training load in elite male road cyclists: a longitudinal study. *J Sports Med Phys Fitness* 47: 191-196, 2007.

29. Zaryski C and Smith DJ. Training principles and issues for ultra-endurance athletes. *Curr Sports Med Rep* 4: 165-170, 2005.

Figure Legends

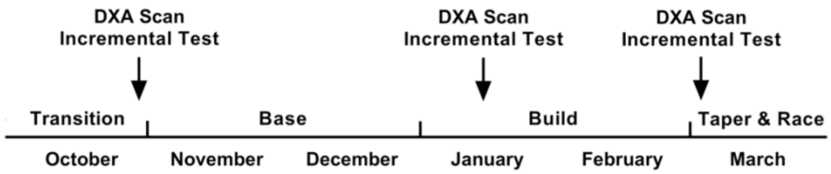

Figure 1 – Timeline of the study. The previous competitive season finished at the end of September, with riders then commencing a transition period, which involved 1 – 2 weeks of inactive break, followed by 2 – 3 weeks of active break. The training period was divided into base and build phases, with the final laboratory testing performed at the start of taper (i.e. twelve days before the Cape Epic).

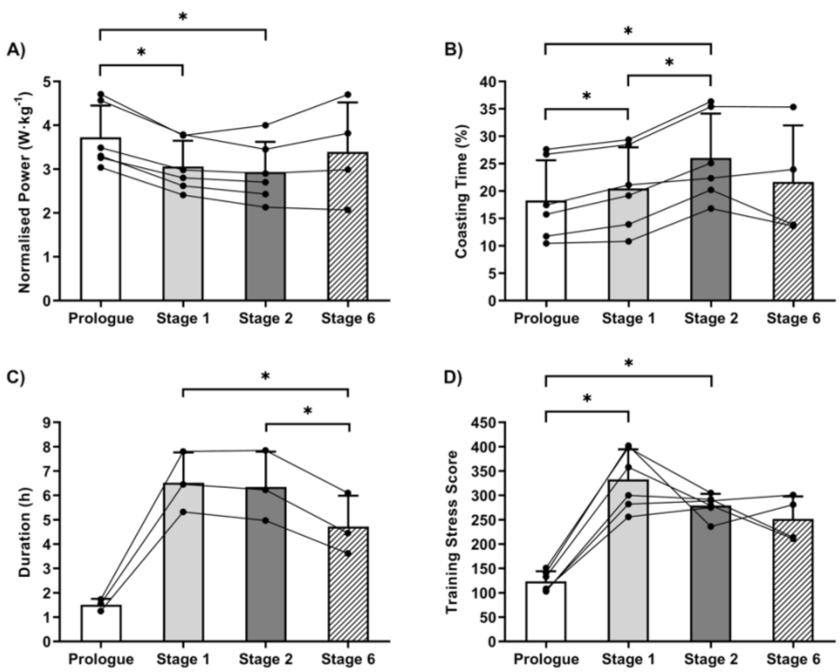

Figure 2 – A) Normalised power, B) coasting time, C) race duration, and D) training stress score per race stage. * denotes significant difference (all P ≤ 0.043).

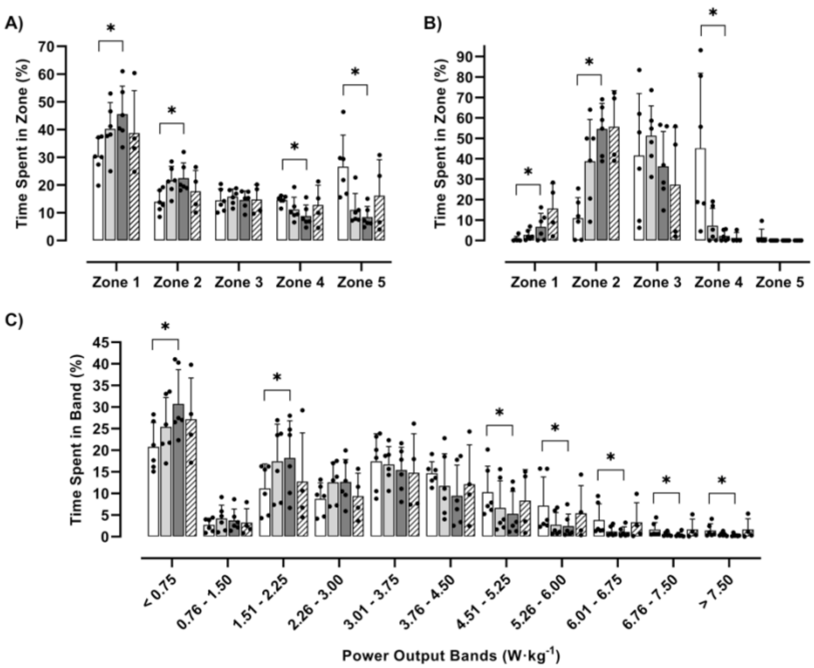

Figure 3 – A) Time spent in power zones, B) time spent in heart rate zones, and C) time spent in power bands per race stage. White bars denote prologue, light grey bars denote stage 1, dark grey bars denote stage 2, and striped bars denote stage 6. * denotes significant difference (all P ≤ 0.012).

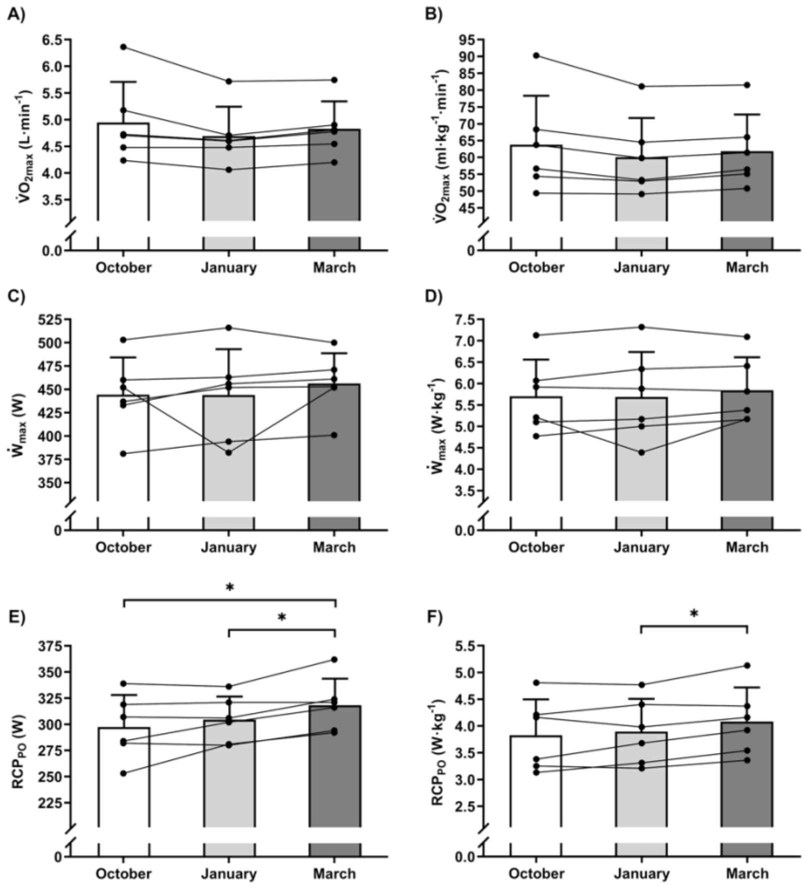

Figure 4 – A) Absolute maximal oxygen uptake ($\dot{V}O_{2max}$), B) relative $\dot{V}O_{2max}$, C) absolute maximal work rate during the incremental test ($\dot{W}_{max}$), D) relative $\dot{W}_{max}$, E) absolute power associated with the respiratory compensation point (RCP_{PO}), and F) relative RCP_{PO} measured at different time points during the season. * denotes significant difference (all $P \leq 0.048$).

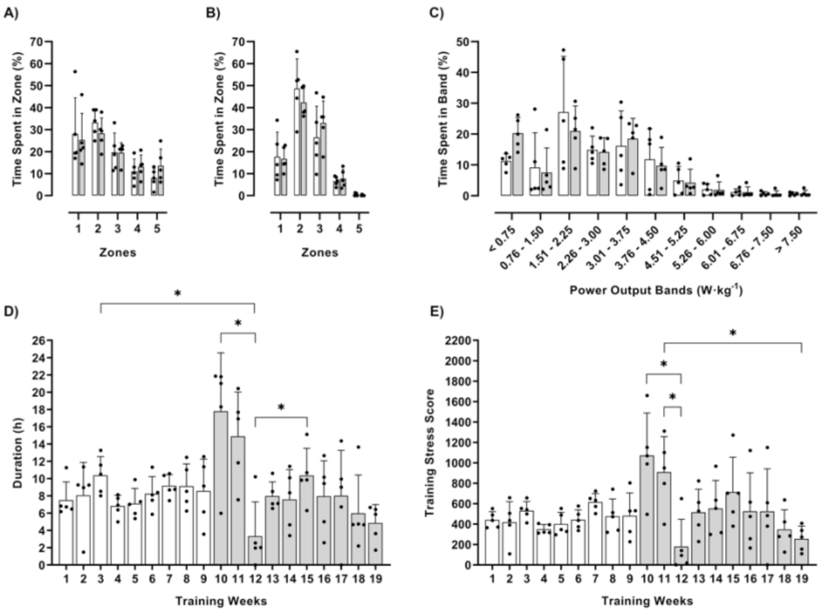

Figure 5 – A) Time spent in power zones, B) time spent in heart rate zones, C) time spent in power bands, D) weekly training duration, and E) weekly training stress score. White bars denote base and grey bars denote build. * denotes significant difference (all $P \leq 0.05$).

Table 1 – Race characteristics retrieved from the Cape Epic official website (http://www.cape-epic.com).

Stage	Temperature (°C)	Humidity (%)	Distance (km)	Vertical Gain (m)
Prologue	23	61	26	700
1	28	58	108	2300
2	26	65	93	2200
3	31	61	104	2150
4	24	76	75	1850
5	24	78	93	2500
6	24	64	69	2100
7	23	58	86	1200
Mean ± SD	25 ± 3	65 ± 8	82 ± 26	1875 ± 614

Table 2 – Power output and heart rate zones.

Zone	$\%RCP_{PO}$	$\%RCP_{HR}$
1	≤ 55	≤ 68
2	56 – 75	69 – 83
3	76 – 90	84 – 94
4	91 – 105	95 – 105
5	≥ 106	≥ 106

$\%RCP_{PO/HR}$: percentage of power output/heart rate associated with the respiratory compensation point.