Epidemiology of swimming induced pulmonary oedema: Occurrence, risk factors and outcomes

by

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Declaration

I declare that the work presented in this thesis is my own and has been carried out in accordance with the regulations of the University of Kent. Except where specific reference is made to the work of others, the content of this thesis is original and has not been submitted, in whole or in part, for any other degree or professional qualification.

Some work presented in chapter 3 is based on the article "Occurrence, risk factors, prognosis and prevention of swimming-induced pulmonary oedema: a systematic review" published in Sports Medicine - Open (Spencer, Dickinson and Forbes 2018).

All such works were developed under the supervision and with the guidance of my supervisors, Professor Lindsay Forbes, Professor John Dickinson and Dr Sarah Hotham. Proper acknowledgments and references have been included throughout the thesis.

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Abstract

Background: Open water swimming is increasingly popular, with an estimated 4.4 million people in England participating in 2022/23. However, there is growing evidence that it is associated with a dangerous condition known as swimming-induced pulmonary oedema (SIPE). SIPE occurs when fluids from the blood leak into the lungs during swimming, causing acute shortness of breath and a cough, which may be productive of blood-tinged sputum. Symptoms usually improve when out of the water, however, SIPE can be life threatening if a swimmer is unaccompanied or cannot leave the water quickly. Despite the danger SIPE poses, awareness among outdoor swimmers, venues, event organisers and health care professionals is lacking, and there is a shortage of epidemiological evidence. I set out to investigate SIPE occurrence, risk factors, symptoms and outcomes, and explore the experiences of affected outdoor swimmers.

Method: To determine the occurrence of SIPE, I carried out a cross sectional study of open water swimmers, using questionnaire surveys of the online open water swimming community and at competitive open water swimming events. Questionnaires were developed and underwent testing and validation with a small group of outdoor swimmers and a panel of experts. They collected information on shortness of breath experienced during swimming, demographics, anthropometrics, medical history, swimming habits and health behaviours. Cases of suspected SIPE were detected using a range of case definitions. To study risk factors, I carried out an unmatched case-control study using cases and controls identified from survey responses. I calculated adjusted odds ratios (ORs) for risk factors using logistic regression, controlling for age, sex and potential confounders. I investigated symptoms, outcomes and experiences of SIPE cases through a case series study.

Findings: My analyses were based on a sample of 1078 outdoor swimmers. Depending on the case definition used, prevalence of SIPE was between 0.1% (95% CI 0.002 to 0.5) and 22.2% (95% CI 19.7

to 24.8) of outdoor swimmers in the UK, and incidence was between 2.8% (95% CI 0.6 to 7.9) and 14.8% (95% CI 8.7 to 22.9) of competitors per open water swimming race.

The risk factors study included 107 cases and 871 controls. Significant risk factors for having ever experienced SIPE included wearing a tight wetsuit or non-tight wetsuit compared to no wetsuit (tight wetsuit: adjusted OR 6.56 (95% CI 3.50 to 12.30); non-tight wetsuit: adjusted OR 2.10 (95% CI 1.27 to 3.48)). Having an asthma diagnosis was also associated with SIPE (OR 2.70, 95% CI 1.73 to 4.21) although evidence for a causal association was limited and it is possible the SIPE case definition lacked specificity. The associations remained similar after attempts to control for potential confounding factors. Age, sex, swimming distance, maximum effort levels or a history of heart disease, hypertension or Raynaud's syndrome were not significantly associated with SIPE.

The case series included 107 cases of SIPE, most of whom did not seek medical attention for their symptoms. Over a third of cases did not experience any symptoms other than shortness of breath. Chest tightness was the most common additional symptom reported. Symptoms were frequently attributed to other causes such as cold shock response, panic attack, asthma, nasal allergies or respiratory infections. Over 70% of the people who experienced symptoms suggestive of SIPE reported having previous similar episodes.

Conclusions: The results suggest SIPE is a significant problem for open water swimmers, and previous studies may have underestimated its occurrence. More studies are needed that can identify milder cases of SIPE to better understand the scale of the problem and the range of symptoms involved. Wearing a wetsuit during open water swimming increases the risk of SIPE. It is important to further explore whether this is causal and what the mechanisms might be. If the association is found to be causal, it may be necessary to address wetsuit design to prevent SIPE. Increasing awareness and understanding of SIPE among outdoor swimmers, venues, event organisers and healthcare professionals is crucial for effective prevention and management.

Table of contents

List of tables

List of figures

List of appendices

Abbreviations

A&E	Accident and Emergency
ADH	Antidiuretic hormone
ECG	Electrocardiogram
HAPE	High altitude pulmonary oedema
ICD	International Classification for Diseases
ICU	Intensive care unit
IPE	Immersion pulmonary oedema
LUS	Lung ultrasound scan
MAP	Mean arterial pressure
MPAP	Mean pulmonary artery pressure
OR	Odds ratio
PAP	Pulmonary artery pressure
PAWP	Pulmonary artery wedge pressure
SEAL	Sea, Air and Land
SIPE	Swimming-induced pulmonary oedema
SOB	Shortness of breath

Chapter 1: Introduction

1.1 Introducing the thesis

Open water swimming is an increasingly popular sport, with an estimated 3.6 million people in England having participated in the past year (Sport England 2024). However, there is growing evidence that it is associated with a condition known as swimming-induced pulmonary oedema (SIPE). SIPE is a type of immersion pulmonary oedema (IPE) that occurs when fluids from the blood accumulate in the air spaces of the lung during surface or underwater swimming, causing acute shortness of breath (SOB) and a cough which may be productive of pink, frothy or blood-tinged sputum (Miller, Calder-Becker and Modave 2010). It can affect people with no underlying health problems. It is thought that in most cases symptoms subside once the individual leaves the water, however, SIPE is potentially life threatening whilst a swimmer remains in the water and some IPE deaths in divers have been documented (Peacher *et al.* 2015). Despite the danger SIPE poses, awareness of the condition among outdoor swimmers, event organisers and health care professionals is lacking.

In their study of USA Triathlon members, Miller, Calder-Becker and Modave 2010) estimated that 1-2% of US triathletes had experienced SIPE. The condition is thought to result from a "perfect storm" of factors, including swimming in cold water, wearing a wetsuit, drinking too much fluid, taking antiplatelet medications, and health conditions such as high blood pressure and heart problems. However, SIPE remains an under-researched area and the occurrence, pathophysiology, risk factors and outcomes are poorly understood.

This study adds to the limited evidence base for SIPE by characterizing its epidemiology among open water swimmers in the UK. My objectives were to investigate the occurrence, risk factors and outcomes associated with SIPE by developing and validating a bespoke questionnaire and using it to conduct a large survey of outdoor swimmers. The findings provide a UK perspective of the condition among competitive and recreational open water swimmers. The intention is that this study will help to guide future research on the prevention, treatment and identification of people at risk, and inform policy on open water swimming safety. The overall impact of the study will be to reduce the occurrence or recurrence of SIPE in at-risk individuals, decrease the potential for harm should SIPE take place, and improve patient care should medical treatment be required.

This chapter introduces the topic of SIPE and provides an overview of the research I have conducted. I will also discuss my reasons for undertaking the study, present my research questions and outline the following chapters.

1.2 Motivation for the study

My interest in this topic dates back to May 2016 when, as a beginner triathlete, I had a frightening experience of SOB whilst swimming in a lake in Kent. Symptoms included extreme SOB out of proportion to the effort being put in, productive cough, wheezing/whistling in the chest, tight chest, disorientation and feelings of panic. Initially I attributed the episode to a panic attack, however, this did not explain the continuation of breathing problems and wheezing for a few hours after I exited the water. I carried out some initial reading and discovered that my symptoms and experience matched almost exactly those described in the literature on SIPE. A few days later, I decided to visit my GP who examined me and found nothing abnormal. They had never heard of SIPE and did not provide any advice. However, due to a problem with persistent high blood pressure, I had previously been referred to a different GP with a special interest in cardiology, to whom I gave an account of my experience in the lake. They made some enquires and later confirmed the symptoms were most likely attributable to SIPE. I was advised to avoid swimming in cold water in future due to the risk of a recurrence. No additional medical advice was given.

The shortage of information and research on SIPE, and the lack of awareness of this dangerous condition among health care professionals, outdoor swimmers, outdoor swimming venues and event organisers inspired me to carry out my own epidemiological research. I wanted to find out how common the condition is among UK open water swimmers, investigate risk factors and outcomes, and learn more about the circumstances and experiences of those who had previously suffered an episode of SIPE.

1.3 Patient and Public Involvement

Before I embarked on the PhD study, I consulted with members of the outdoor swimming community to inform study design and ensure the research was relevant and ethical. As a member of Ashford Triathlon Club, I added a post to the club Facebook page asking to hear from people who had experienced breathing problems whilst outdoor swimming. I did the same on another local triathlon club's Facebook page (with permission), and a number of online swimming and triathlon forums. I received nine responses specifying different types of breathing issues, including cold shock response, asthma related problems, hay fever symptoms, and other unexplained breathlessness and coughing. I followed up the responses in the latter category with telephone conversations with four individuals. After receiving an account of their experiences, I spoke about the study and the proposed methodology, asking for comments. These conversations and the online responses highlighted the need to differentiate clearly between SIPE symptoms and other types of breathing problems. In order to get a wider perspective, I had discussions with four non-triathlete outdoor swimmers, including a cross-channel swimmer who had written a blog about his recent experience of SIPE.

The feedback I received about the research topic and proposed methodology was positive, with remarks about the importance of learning more about SIPE. It was agreed that Facebook was a good method for recruiting respondents and that incentives such as sports shop vouchers to maximise responses would be helpful. My discussion with the cross-channel swimmer was extremely beneficial as he was a very well connected outdoor swimmer and was able to add me to the most popular outdoor swimmer Facebook groups and online forums. He gave me a full account of his experience and spoke of at least 15 others that had contacted him regarding their own experience of SIPE. He also had some suggestions of hypothesized risk factors which may require further investigation.

All the triathletes and outdoor swimmers that I spoke to were happy to be involved in the project. I invited these individuals and others to comment on my plain English summary, regarding its understandability and the proposed methods. All feedback was positive with no suggestions for improvement.

1.4 Background

1.4.1 Cold water swimming

According to Katzmarzyk *et al.* (2022), 9.1% of deaths in the UK are attributable to physical inactivity. Being physically active is known to have huge health benefits, such as helping to prevent and manage many chronic conditions, and improving mental health and wellbeing (Public Health England 2014). In the UK, endurance sports such as marathon running, triathlons (outdoor swimming, cycling and running) and long distance open water swimming are increasingly popular ways to increase physical activity. According to the most recent Active People Survey 2021/2022, 606,800 people had taken part in open water swimming in the previous month (Sport England 2024). The popularity of this sport is most likely due to the many reported benefits of cold water swimming, such as improvements to mental wellbeing and the cardiovascular, endocrine and immune systems (Knechtle *et al.* 2020). However, cold water swimming can pose several health risks, including hypothermia, cold shock, and SIPE.

1.4.2 Early research

Before SIPE was recognised in surface swimmers, a similar phenomenon had been described in scuba divers. Immersion pulmonary oedema (IPE) was first documented in scuba divers by Wilmshurst *et al.* (1981). Then in a later publication, Wilmshurst *et al.* (1989) recorded a similar phenomenon in surface swimmers. However, since then research has been limited and the mechanism is still poorly understood.

Immersion pulmonary oedema is thought to occur because of the extrinsic pressure of water on the body during immersion, which forces blood away from the extremities into the chest. This, along with cold water induced vasoconstriction, causes an increase in pressure gradients across pulmonary capillaries, which eventually causes a leakage of fluid into the air spaces in the lung. Symptoms of IPE can range from mild SOB to severe SOB together with cough, chest tightness, chest crackles, coughing up bloody/frothy sputum and/or hypoxia. In most cases, symptoms resolve within 48 hours of exiting the water, however, in severe cases, continued immersion in water can lead to loss of consciousness and/or drowning.

In their early studies of IPE, Wilmshurst *et al.* (1981, 1989) reported a small number of individuals (n=3, n=11 respectively) who experienced recurrent episodes of pulmonary oedema during diving or surface swimming in cold water. Both studies found the affected divers had a more exaggerated vascular response to cold stimuli than non-affected divers. The authors suggested the increased cardiac preload and afterload, along with the increase in central blood volume, may explain the occurrence of pulmonary oedema in these individuals.

Another study was published in 1995 by Pons *et al.* which reported pulmonary oedema in four individuals during swimming or scuba diving in cold Swiss lakes. However, in contrast to Wilmshurst *et al.*, Pons *et al.* found no differences in the vascular response to cold exposure in these patients compared to healthy volunteers. The authors questioned whether exposure to cold temperatures was an important factor in the development of immersion pulmonary oedema.

In the same year Weiler-Ravell *et al.* (1995) described eight cases of pulmonary oedema among Israeli military trainees during a swimming time trial. At 23^{o}C, the water was warmer than in previous studies, however, the young men swam at high levels of exertion and had each consumed five litres of water in the two hours before swimming. The authors suggested this combination of immersion, exertion and fluid overload may have caused an increase in pulmonary capillary pressures that eventually caused fluid to leak into the air spaces in the lung.

In 1995, a case of pulmonary oedema in a breath-hold diver was reported for the first time by Boussuges *et al.* (1995). Another three cases were reported by Boussuges *et al.* in 1999. In both articles, the authors suggested the aspirin the divers had taken beforehand might have been a factor.

1.4.3 Types of immersion pulmonary oedema

There has been some debate around whether the different forms of pulmonary oedema that occur in swimmers, scuba divers and breath-hold divers should be considered separately. Davis (2016) argued that because the pathophysiological processes are the same whatever the circumstances, they should all be termed immersion pulmonary oedema. However, Edmonds (2016) believed the three should be separated due to the "considerable differences in the epidemiology, aquatic behaviour and physical stressors in each of these three groups". He argued that the circumstances of an elite swimmer/triathlete swimming at the surface and breathing air are very different from a heavily equipped unfit elderly scuba-diver under high hyperbaric pressures with the potential exposure to gas toxicity. Breath-hold divers are uniquely affected by a high ambient pressure on the lungs which can cause damage known as pulmonary barotrauma or lung squeeze (Lindholm and Lundgren 2009). For these reasons, I decided to restrict this study to SIPE in surface swimmers.

1.4.4 Occurrence of SIPE

Despite the passing of almost 30 years since the first studies of IPE, research on SIPE is still lacking, particularly in recreational outdoor swimmers. A US survey in 2009 suggested that 1–2% of triathletes had experienced SIPE symptoms (Miller, Calder-Becker and Modave 2010), however, the authors felt this was probably an underestimate. No other large studies of SIPE prevalence in swimmers or triathletes have been published. The Active Lives Survey 2023 estimated there were 213,000 active triathletes in England (Sport England 2024). Applying the 1–2% estimate to this population equates to 2,100–4,300 triathletes who may have experienced SIPE.

Establishing the true occurrence of SIPE is challenging due to difficulties in identifying cases. The absence of a standardised case definition means that those used vary greatly, from mild unexplained breathlessness during swimming, to extreme SOB accompanied by coughing and blood stained sputum, plus x-ray or ultrasound scan evidence. Often it is the stricter case definitions involving more severe symptoms that are used, since these patients normally require medical intervention so can be detected from medical records, unlike those with milder symptoms that resolve without medical assessment. In cases where a patient receives a diagnosis of SIPE and requires hospital treatment, the absence of a specific International Classification for Diseases (ICD) diagnosis code with which to record it can prevent the case from being identified later from secondary data sources such as hospital inpatient data.

1.4.5 Risk factors

SIPE is thought to be associated with a "perfect storm" combination of risk factors. Authors have suggested these may include the following; cold water immersion, female sex, older age, pre-existing medical conditions such as hypertension, antiplatelet medications and supplements, over-hydration, long swim distance, wetsuit use, swimming position, exertion and failure to warm up (Koehle, Lepawsky and McKenzie 2005; Miller, Calder-Becker and Modave 2010; Weiler-Ravell *et al.* 1995; Shupak *et al.* 2000). However, few studies have examined these risk factors at population level.

1.4.6 Medical care

A British Thoracic Society Clinical Statement recommends that swimmers that require treatment for SIPE should be taken out of the water, warmed and restrictive clothing removed (Hull *et al.* 2022). It suggests acute treatment should be considered on a case-by-case basis, and may include oxygen, diuretics, and beta-2 agonists. Clinicians are encouraged to carry out cardiac investigations to rule out structural heart disease. The guidance also suggests swimmers should be advised on the risk of a recurrence, and of modifiable risk factors such as water temperature, tight wetsuits, and over consumption of water or salt before swimming. For older hypertensive swimmers, adjustments to antihypertensive medication dosage may be required. Use of the drug sildenafil to reduce the risk of a recurrence is mentioned, however, this must only take place under expert supervision.

1.5 Deaths from SIPE

Annual reports from the UK Water Incident Database (WAID) show that over the period 2019 to 2023, an average of 36 people died each year in the UK as a result of swimming in open water (National Water Safety Forum 2020; 2021; 2022; 2023; 2024). However, the number of deaths attributable to SIPE is unknown due to difficulties differentiating between a simple case of drowning and death due to natural disease or injury. This is because in most water related deaths, aspiration of water into the airways will have occurred (Papadodima *et al.* 2010). A full autopsy, which also takes into account circumstantial evidence is often required, however, many water related deaths remain unexplained with no clear cause of death ever established. For example, out of 3,126 water related fatalities in UK waterways between 2019 and 2023, there were 755 deaths where the cause was unrecorded or unknown, meaning almost a quarter remained unexplained deaths (National Water Safety Forum 2020; 2021; 2022; 2023; 2024).

In their study of 23 post mortem reports of swimming related deaths of triathletes, Moon *et al.* (2016) suggested some triathlete deaths with no obvious cause may be attributable to SIPE. Although there is currently little evidence to suggest SIPE related deaths are anything but a rare occurrence (Asplund and Creswell 2016; Yao *et al.* 2024; Eichner 2011; Dressendorfer 2015; USAT 2012), it could be argued that many SIPE attributable deaths remain undetected due to the difficulties in identifying SIPE as a cause of death. Even when SIPE is established as the cause of death, the lack of an ICD diagnosis code makes it hard to identify the death from secondary datasets such as Office for National Statistics (ONS) mortality records.

1.6 Why this matters

With the rising popularity of endurance sports and events that involve outdoor swimming, the potential for SIPE to occur is increasing, however, awareness of the condition among open water swimmers, event organisers, and healthcare professionals remains low (Smith *et al.* 2016). This often leads to SIPE symptoms being ignored or attributed to other causes, while individuals continue with their swim, potentially putting them at risk of drowning. It also means that swimmers may not seek medical attention, or if they do, healthcare professionals may mistake SIPE for other conditions such as asthma or panic attacks, resulting in inappropriate treatment. Recognising SIPE quickly is essential for providing the correct medical care in a timely fashion. Identifying and responding to SIPE quickly is of particular importance in remote, open water settings where emergency medical assistance may not be immediately available. Understanding SIPE better also helps in developing strategies for prevention of recurrences in at-risk individuals.

This study will improve the knowledge base around SIPE and will produce information that can used to inform policy and guidance on SIPE and water safety for outdoor swimmers. It will also inform healthcare professionals about SIPE to ensure the condition can be diagnosed and treated quickly and effectively, and steps can be taken to prevent it from happening again in individuals. Ultimately, the results of this study will provide evidence to guide open water swimmers, event organisers and clinicians in the prevention and management of SIPE.

1.7 Research questions

This study was mainly concerned with the epidemiological aspects of SIPE, although it also describes the pathophysiology of SIPE as far as current understanding goes. My research questions were as follows:

1. What is the prevalence of having experienced SIPE?
2. What is the incidence of SIPE?
3. What are the risk factors for SIPE?
4. What are the short-term outcomes of SIPE i.e. hospitalisation, death, recovery?
5. What is the recurrence rate of SIPE?

1.8 Organisation of the study

This thesis is organised into the following eight chapters:

Chapter 1 – Introduction. This chapter introduces the topic, presents my research questions and summarises the structure of the thesis.

Chapter 2 – Pathophysiology. This chapter describes the physiological responses to cold water swimming and the mechanisms that might lead to an occurrence of SIPE. It also describes some the characteristics and behaviours of individuals that might increase the risk of SIPE.

Chapter 3 – Systematic Review. The chapter reviews published literature relevant to the occurrence, risk factors, prognosis and prevention of SIPE.

Chapter 4 – Questionnaire design, testing and validation. This chapter describes the process I went through in developing questionnaires to identify people who have experienced SIPE, and collect information on risk factors and outcomes.

Chapter 5 – Occurrence of SIPE. The chapter reports two linked studies I undertook to investigate the incidence of SIPE and the prevalence of ever having experienced SIPE, in outdoor recreational swimmers in the UK.

Chapter 6 – Risk factors for SIPE. In this chapter I identify the characteristics and behaviours of outdoor swimmers that increase their risk of experiencing SIPE.

Chapter 7 – SIPE case series. This chapter reports the characteristics of SIPE episodes experienced by cases identified in this study, including associated symptoms, perceived attribution of symptoms, medical attention, and previous similar episodes. It also provides details of the individual experiences of three cases.

Chapter 8 – Conclusion and recommendations. This chapter reviews the research questions and summarises the limitations of the study. It then recommends areas for future research and discusses the implications for policy and practice.

Chapter 2: Pathophysiology

2.1 Introduction

This chapter discusses the hypothesized physiological mechanisms that are thought to lead to an episode of SIPE. It also examines the physiological effects of swimming in cold water and the multitude of factors that can affect the severity of the response. Understanding the pathophysiology of SIPE is of particular importance when considering potential risk factors and demonstrating a plausible mechanism through which the risk of SIPE may be increased.

SIPE is characterised by pulmonary oedema that occurs during swimming, resulting in symptoms such as SOB, and signs such as basal crackles on auscultation, in people who do not have a clear cardiac cause. X-rays and ultrasound scans of SIPE cases have resulted in findings consistent with pulmonary oedema (Grünig *et al.* 2017; Wilmshurst 2019; Hårdstedt *et al.* 2020).

2.2 Mechanisms for pulmonary oedema

Pulmonary oedema occurs when fluid enters the air spaces in the lungs (alveoli) from blood in the capillaries surrounding them (Murray 2011). This reduces the area available for gas exchange. There are three principal mechanisms of pulmonary oedema:

1. Increased hydrostatic pressure in pulmonary circulation.
2. Increased capillary permeability in alveoli due to damage to the interface between the capillary and alveolus (Claesson-Welsh 2015).
3. Low plasma oncotic pressure (osmotic pressure exerted by plasma proteins).

Sometimes it is a combination of the above that causes pulmonary oedema. I describe each of these mechanisms in more detail below.

2.2.1 Increased hydrostatic pressure in pulmonary circulation

Blood pressure in the pulmonary circulation is approximately one tenth the pressure of the systemic circulation. Average pulmonary arterial pressure is around 9-16 mmHg whereas average systemic arterial pressure is around 90 mmHg (Yartsev 2022). In normal circumstances, the walls of capillaries are more permeable to water and solutes than the walls of the alveoli. Any fluid that leaks out of the capillary into the interstitial space is cleared by the lymphatic system. However, when the hydrostatic pressure in the pulmonary circulation increases, protein-poor fluid builds up in the interstitial space and can exceed the ability of the lymphatic drainage to clear it. Fluid therefore accumulates in the interstitial space before it eventually breaches the alveolar endothelium.

This type of pulmonary oedema most often has a cardiac cause where the heart is unable to pump sufficient blood around the circulatory system without a rise in venous pressure. In left heart failure, the left side of the heart is less able to pump blood around the body. In right heart failure the right side of the heart is less able to pump blood towards the lungs. Causes of heart failure include ischaemic heart disease, heart valve disease and arrhythmias. Increased hydrostatic pressure in pulmonary capillaries can also be due to non-cardiac reasons such as an excess of fluid in the body caused by administering too much intravenous fluid, or poor kidney function leading to insufficient urine production.

2.2.2 Increased capillary permeability in alveoli

In this situation, the membrane between the capillaries and alveoli becomes damaged and leaky, allowing water and proteins from the intravascular space to permeate into the alveoli (See Appendix 1). The causes of this damage include infections, and inhaled or injected toxins among others. The commonest cause is sepsis or viral pneumonia, which are associated with high levels of cytokines produced by the immune system which increase the permeability of the capillaries. The neutrophils and microphages that flow into the alveoli along with the fluid can cause more damage to the alveolar membrane, which then allows more movement of water and proteins from the capillary into the interstitial space and alveoli (Ware and Matthay 2005).

2.2.3 Decreased plasma oncotic pressure

Oncotic pressure is a type of osmotic pressure created by the presence of plasma proteins in the blood, that draws fluid back into the capillary from the extravascular tissues. Low levels of plasma proteins in the blood cause the oncotic pressure to drop, so less fluid returns to the capillary. Low levels of plasma proteins may be a result of extremely low intake of proteins or loss of proteins in the urine or liver failure, for example.

2.2.4 Combination of above factors

Sometimes it is a combination of the above that causes pulmonary oedema; that is, increased hydrostatic pressure, low oncotic pressure and increased capillary permeability. For example, if plasma oncotic pressure is low due to a lower concentration of proteins in the blood, this reduces the critical hydrostatic pressure at which fluid will start to enter the alveoli, than if the oncotic pressure is high. Alternatively, high hydrostatic pressure can cause damage to capillaries surrounding the alveoli, thereby increasing their permeability. It may be the case that all three factors combine to cause pulmonary oedema, when each on its own would not have this effect. For example, a situation where slightly low levels of protein in the blood, slightly high right atrial pressures and slightly increased capillary permeability produce a perfect storm of conditions that lead to pulmonary oedema.

2.3 Mechanisms for SIPE

It is not clear exactly which of the above mechanisms causes SIPE, although in a clinical trial, Moon, Martina, Peacher and Kraus (2016) found that participants with a history of SIPE had higher mean pulmonary artery pressures during exercise in cold water, compared to the control group, when adjusted for cardiac output. Studies of high-altitude pulmonary oedema (HAPE) have also reported higher pulmonary artery pressures in HAPE-susceptible subjects during exercise at sea-level, compared to controls (Eldridge *et al.* 1996; Podolsky *et al.* 2013).

It is unlikely that increased capillary permeability or decreased oncotic pressure on their own lead to SIPE. This is because people with conditions that lead to these are usually very unwell, requiring urgent medical care to aid recovery and are therefore not likely to be swimming recreationally. SIPE, on the other hand, tends to affect fit, otherwise healthy people, with symptoms usually resolving fairly rapidly when out of the water, without the need for medical treatment.

In the International Olympic Committee Manual of Emergency Sports Medicine, the mechanism for SIPE is described in the following way:

> *"The pathophysiology is thought to be overperfusion caused by the increase in ambient pressure, peripheral vasoconstriction from ambient cold, and increased pulmonary blood flow resulting from exercise. High pulmonary capillary pressures lead to extravasation of fluid into the interstitium resulting in hypoxemia and secondary pulmonary edema". (Mountjoy and Marks 2015).*

The following section discusses how swimming might lead to an increase in pulmonary hydrostatic pressures that result in capillary leakage.

2.3.1 Reflex responses to cold water

Cold shock – tachycardia, gasping and uncontrollable hyperventilation – is a reflex response that happens within the first three minutes of immersion in cold water. It can lead to aspiration of water and is considered to be one of the main causes of immersion deaths (Tipton and Bradford 2014). It is initiated by the sudden cooling of the skin and is maximised at water temperatures between 15°C and 10°C, although it has been reported at temperatures of up to 25°C (Tipton *et al.* 2017).

The diving reflex is triggered by submerging of the head and face. This, unlike the cold shock reflex, causes bradycardia and apnoea. The slowing of the heart rate works in opposition to the heart rate increase caused by cold shock and peripheral vasoconstriction, and can lead to autonomic conflict, sometimes resulting in cardiac arrhythmias, even in young, healthy individuals (Tipton *et al.* 2017). The diving reflex also causes bronchoconstriction to conserve oxygen during breath holding, leading to reduced lung volumes.

Neither the cold shock nor the diving reflex are likely to be implicated in SIPE, because SIPE occurs at least several minutes after starting to swim.

2.3.2 Physiological responses to cold water

Swimming in water that is colder than body temperature requires the body to react to three different stimuli simultaneously; cold temperature, immersion in water, and physical activity.

2.3.2.1 Effects of cold temperature

Immersion in water that is colder than body temperature leads to peripheral vasoconstriction. Blood is therefore redirected towards the thorax and abdomen, away from the peripheries. The increased venous return leads to an increase in cardiac preload. Cardiac output (stroke volume × heart rate) increases as a result. This, and increased vascular resistance caused by peripheral vasoconstriction, leads to increased systemic and pulmonary artery pressures. Increased core blood volume during immersion leads to a reduction in antidiuretic hormone production and therefore increased urine output by the kidneys. The effect of the cold is counteracted by heat generated by muscles through increased physical activity or shivering, or brown adipose tissue metabolism.

In their review article, Pendergast *et al.* (2015) suggest the diuresis effect peaks at around two hours, although renal hormones remain elevated. Whether this occurs during the usual length of immersion for open water swimmers is not clear.

2.3.2.2 Effects of hydrostatic pressure

During immersion, water exerts a compressive force on the body, known as hydrostatic pressure. This pressure is much greater than air pressure due to it having a density over 800 times greater than air (Wilcock, Cronin and Hing 2006). It increases in proportion to depth. Hydrostatic pressure displaces blood from the lower extremities to the thorax and abdomen, increasing venous return, cardiac output and systemic and pulmonary artery pressures. The increase in blood volume in the central cavity leads to immersion diuresis, which reduces the amount of antidiuretic hormone produced, resulting in an increase in urine production. The effect is greater during immersion in cold water, due to combined effect of cold water diuresis and immersion diuresis.

The increase in hydrostatic pressure also compresses the thoracic cavity. This causes a reduction in lung volumes and compliance, meaning the respiratory muscles have to work harder to move air in and out of the lungs.

2.3.2.3 Effect of physical exercise

During physical exercise, muscle 'pumping' effects in the limbs increase venous return, and cardiac output increases as a result. At maximal rates of work, 80% of cardiac output is received by skin and skeletal muscles, compared to just 20% at rest (Rowell 1983). The rise in cardiac output also increases pulmonary blood flow (Naeije and Chesler 2012). Venous return is greater during swimming than during running, because of the additional effect of hydrostatic pressure on limbs. In addition, the horizontal position of swimmers means that venous return is not reduced by gravity in the way that it would be for people doing exercise in a vertical position.

2.3.2.4 Effects of physical exercise in cold water

As the temperature of the body increases during exercise, peripheral blood vessels dilate to release heat. However, if insufficient heat is generated by muscle contractions, cold-induced vasoconstriction will inhibit the flow of blood to muscles, decreasing the supply of oxygen and removal of waste products. This leads to muscles having to operate anaerobically at lower workloads, resulting in the earlier buildup of blood lactate and quicker decline in carbohydrate stores. This results in fatigue happening sooner in colder water than warmer water (Jacobs, Romet and Kerrigan-Brown 1985). During swimming, the increased blood flow to working muscles lessens their ability to provide insulation to the body, meaning that subcutaneous fat is more important for keeping warm.

Exercise in cold water also affects kidney function. For example, in their review Pendergast *et al.* (2015) suggest that exercise during head out of water immersion lessens diuretic responses, causing an increase in antidiuretic hormone production and sodium reabsorption, and decrease in urine output.

2.3.2.5 Additional challenges of endurance swimming

Sea swimmers can experience a buildup of salt in the mouth and throat from sea spray or mouthfuls of salt water. Over long periods of endurance swimming, this can cause mucous membrane surfaces to become inflamed causing painful swallowing, making it difficult to consume food and fluids (Klemperer and Thomas 2014). This increases the risk of dehydration, which is further exacerbated by the cold water diuretic effect that causes the kidneys to increase the amount of fluid lost through urination. Longer swims can also increase the risk of hypothermia because core temperature can fall dangerously low during prolonged immersion if insufficient heat is generated through the exercise.

Table 1 below summarizes some of the main physiological effects of cold exposure, immersion and exercise that are described above.

Table 1: Summary of physiological responses to cold exposure, immersion and exercise

Response	Mechanism	Details
Cold	Peripheral vasoconstriction	↓ heat loss ↑ venous return ↑ heart rate ↑ stroke volume ↑ cardiac output ↑ pulmonary artery pressure ↑ systemic blood pressure
	Thermogenesis	↑ metabolic heat production of muscles by increased activity or shivering
	Cooling of working muscle	↓ muscle contractile force ↓ power output ↑ fatigue ↑ shivering to replace heat lost
	Cold diuresis (initial response of kidneys)	↓ ADH to reduce blood volume ↑ urine output
Hydrostatic squeeze	Compression of veins	↑ venous return ↑ heart rate ↑ stroke volume ↑ cardiac output ↑ pulmonary artery pressure ↑ systemic blood pressure
	Immersion diuresis	↓ ADH to reduce blood volume ↑ urine output
	Restriction of expansion of lungs	↑ work to inflate lungs and generate negative airway pressure during inspiration
Exercise i.e. swimming	Muscle pumping effect	↑ venous return ↑ heart rate ↑ stroke volume ↑ cardiac output ↑ pulmonary artery pressure ↑ systemic blood pressure ↑ blood flow to skin for cooling ↑ sweating
	Long distance swimming	↑ risk of dehydration, particularly in salt water ↑ risk of hypothermia
Horizontal body position	Haemodilution effect	↑ venous return ↓ heart rate ↑ stroke volume ↑ cardiac output ↓ pulmonary artery pressure ↓ systemic blood pressure

↑= increase in; ↓= decrease in; ADH = antidiuretic hormone

2.4 Variation in physiological responses to swimming in cold water

The physiological effects of swimming in cold water can vary greatly between individuals and environments, due to a number of factors.

2.4.1 Body composition

Body shape and mass have a significant effect on the rate at which heat is lost during exposure to cold temperatures. Heat loss happens mostly through the skin, therefore the larger the skin surface area, the more heat will be lost. Body mass has the opposite effect, with a larger body mass more able to stay warm due to a greater amount of heat being generated through metabolism. It is the combination of these two factors i.e. ratio of surface area to body mass that has a big impact on heat loss. All other things being equal, an individual with a larger surface area to body mass ratio will cool more rapidly than someone with a smaller surface area to body mass ratio (Toner and McArdle 1988).

Levels of body fat and muscle mass are important factors that affect thermoregulation. Body fat has a higher thermal resistance to heat conduction (insulation) compared to skin or muscle. Subcutaneous fat in particular is a very effective insulator, which counteracts cold induced vasoconstriction and shivering. Taller, leaner individuals are therefore likely to cool more quickly than short obese people, as they have a larger surface area to body mass ratio and less fat to act as insulation. Non-working muscle can also act as an insulator (Bierens *et al.* 2016). Individuals with a higher lean body mass i.e. more muscle, generate a greater amount of heat through metabolism.

Higher levels of body fat and a more peripheral distribution of body fat increase buoyancy during swimming (Lazar *et al.* 2013). This reduces energy costs for a given distance, compared to lean swimmers.

In overweight/obese individuals, cold exposure does not lead to as great a blood pressure response compared to non-overweight/obese people (Grewal and Gupta 2020; Grewal *et al.* 2015; Monteiro, Chathoth and Kadur 2012; Garg *et al.* 2013). It is thought this effect may be due to overweight or obese individuals having a reduced sympathetic nervous system response (Grewal and Gupta 2020), which plays a crucial role in controlling the diameter of blood vessels. This may also help to explain the reduced cardiovascular response of obese adults to exercise compared to non-obese individuals observed by Gondoni *et al.* (2009). The authors found that obese individuals had a lower peak heart rate than non-obese subjects during an exercise stress test, and their heart rate took longer to return to pre-exercise levels.

2.4.2 Age

Older individuals are less able to detect a change in temperature through their skin (Smolander 2002). This lowers the temperature at which shivering and vasoconstriction are triggered, thereby reducing their ability to thermoregulate (Frank *et al.* 2000; Holowatz and Kenney 2010). This reduced vasoconstriction leads to smaller increases in stroke volume and coronary blood flow during cold stress, compared to young adults (Li, Wang and Cheng 2022). However, blood pressure following core body cooling has been reported to increase more in the elderly compared to young adults (Li, Wang and Cheng 2022). Older people have also been found to have a less pronounced haemodynamic response to immersed exercise, with one study showing no change in stroke volume compared to a significant increase in young adults (Takeshima, Narita and Matsui 2018).

In addition to reduced vasoconstriction, people aged 60 and over have lower daily energy expenditure compared to younger people, and therefore produce less metabolic heat (Pontzer *et al.* 2021). This means they are less able to preserve body heat during exposure to the cold. It is thought the lower energy expenditure may be due to reduced levels of physical activity, and the loss of lean muscle mass and brown adipose tissue that happens during the ageing process. A decline in physical fitness with age also means that older individuals are likely to fatigue earlier than their younger counterparts, which also reduces heat generation.

2.4.3 Sex

Women may experience a more rapid onset of vasoconstriction during cold exposure. For example, Bartelink *et al.* (1993) reported lower finger skin temperatures and blood flow during cold exposure in women compared to men. Furthermore, Candas and Dufour (2007) found during the early stages of cooling, hand blood flow in women was nearly half that observed in men, however, there were no significant differences between the sexes by the end of the cooling phase.

The physiological response of women to cold exposure is also affected by hormonal fluctuations during the menstrual cycle, with an increased vasoconstriction response and slower recovery during the luteal phase compared to the follicular phase of the cycle when it is similar to men with equivalent fitness levels (Wittmers and Savage 2001).

Toner and McArdle (2011) argued that differences in the responses of males and females to cold exposure were mainly due to anthropometric and body composition differences. They suggest the larger muscle mass in men means they produce more metabolic heat, however, Tikuisis *et al.* (2000) point out that this is in proportion to body mass, so men and women of similar body mass produce a similar amount of heat. Shivering initiates at higher temperatures in women compared to men (Kaikaew *et al.* 2018). Women also have a greater surface area to body mass ratio, which leads to more rapid heat loss when exposed to cold temperatures.

Women's bodies contain a greater proportion of fat than men and often have a thicker layer of subcutaneous fat that can provide a greater amount of insulation. Women tend to experience greater buoyancy during immersion due to their greater proportion of body fat which reduces energy costs for a given distance compared to men, resulting in a faster speed for a given energy expenditure (Lazar *et al.* 2013). Women also have smaller diameter airways, smaller lungs and lower lung volumes compared to men, which increases the work of breathing during exercise (Lomauro and Aliverti 2018).

2.4.4 Cold shock habituation

Studies have shown that cold water habituation or immersing oneself in cold water repeatedly over a number of days, can lessen the severity of the body's reaction to the cold i.e. cold shock response, vasoconstriction and shivering (Tipton *et al.* 1998). It is important to note that the cold shock habituation can be partially reversed in the presence of certain factors, such as acute anxiety (Barwood *et al.* 2013).

2.4.5 Longer term adaptation

Regular cold water swimmers undergo a longer term adaptation known as metabolic habituation. This involves changes in the body's ability to maintain core temperature during prolonged periods of deep tissue cooling, which means that the onset of shivering is delayed (Tipton *et al.* 2013; Hingley *et al.* 2011).

2.4.6 Physical fitness

In physically fit people, the heart gets larger, particularly the left ventricle, to accommodate a higher stroke volume. This means the heart muscle increases in thickness and the volume of the heart chambers increases. Maximal cardiac output rises which increases the delivery of blood to muscles. Capillary density in trained muscles is increased as new capillaries form and existing capillaries become open to flow.

Endurance training increases tidal volume (the volume of air moved into or out of the lungs during a normal breath) and reduces breathing frequency. This leads to better oxygen uptake in the alveoli. This pattern of ventilation reduces the fatigue in muscles used for breathing and frees up oxygen to be used by non-respiratory active muscles.

Endurance training may also lead to a changed vasomotor pattern. Bittel *et al.* (1988) found the skin temperatures of fit subjects stayed warmer than less fit subjects during rest in cold air. However, other researchers have found that endurance training increases the vasoconstrictor response to cold (Young, Sawka and Pandolf 1996).

2.4.7 Health conditions and medications

Some health conditions affect the body's response to cold temperatures. For example, hypertension may change skin vasomotor responses (Alba, Castellani and Charkoudian 2019). Raynaud's phenomenon is a condition whereby the body overacts to cold (or emotional stimuli) leading to excessive vasoconstriction in fingers and toes. Several common medications are known to affect the cardiovascular system, for example beta-blockers, calcium channel blockers and salbutamol.

2.4.8 Hydration status

Proper hydration is crucial to maintaining the body's fluid balance during cold water swimming. For example, overhydration due to excessive fluid intake during long distance swims can lead to exercise induced hyponatraemia (abnormally low sodium levels in the blood). Initially this may cause a mild headache, vomiting and fatigue, but can later lead to epileptic seizures, muscle cramps, swelling of hands and feet, and drowsiness (Knechtle et al. 2019). The body will attempt to restore fluid balance through urination, however, there is some anecdotal evidence to suggest that urinating during cold water swimming may be difficult for some individuals (Munatones 2012).

Inadequate fluid intake during swimming can lead to hypohydration (lower than normal body water). A recent paper reviewed evidence on the effect of hypohydration on cardiovascular health and concluded that hypohydration impaired cutaneous vascular function, reduced endothelial function and affected the regulation of blood pressure during exercise (Watso and Farquhar 2019).

2.4.9 Wetsuits

Wetsuits and other specialized clothing are effective ways in which to regulate body temperature during cold water immersion through reducing the amount of heat that dissipates. However, there is some evidence that wetsuits can affect cardiovascular and respiratory function. Prado *et al.* (2017)

reported higher mean arterial pressures among 12 male subjects when tight-fitting triathlon wetsuits were worn during resting in dry conditions, compared to no wetsuit. There was no difference between no wetsuit and wearing the largest wetsuit that would fit according to manufacturer recommendations. In a study of 24 divers, Marabotti *et al.* (2017) found that wearing diving wetsuits in dry conditions decreased heart rate, cardiac output and right ventricular early diastolic filling and increased total peripheral resistance. The compression effect of diving wetsuits has also been shown to have a diuretic effect, reducing plasma volumes and increasing urine output in dry conditions as well as during immersion. However, during immersion, the wetsuit pressure effect merged into the larger main effect of hydrostatic pressure (Castagna *et al.* 2013). Marabotti *et al.* (2017) observed respiratory effects of wearing a diving wetsuit, such as a decrease in vital capacity and expiratory reserve volumes, and an increase in inspiratory capacity and tidal volume.

2.5 Conclusion

It appears the main mechanism for SIPE is an increase in pulmonary artery pressure (PAP), which forces fluid out of the pulmonary capillaries and into the surrounding lung tissue. This is mainly due to evidence which suggests that individuals who have experienced SIPE have higher PAP during immersed exercise compared to those who have not (Moon, Martina, Peacher, Potter, *et al.* 2016). Similarly, higher PAP in HAPE susceptible people during exercise at sea-level have been reported (Eldridge *et al.* 1996; Podolsky *et al.* 2013). It is possible that increased capillary permeability may also be a factor. Although there is a lack of clear empirical evidence for the mechanisms by which risk factors cause high PAP, there are many hypotheses based on theoretical evidence.

Chapter 3: Systematic review

3.1 Introduction

This chapter provides a review of evidence on SIPE incidence, prevalence, risk factors, short and long term outcomes, recurrence and effectiveness of interventions to prevent recurrences. It includes a description of the literature search strategy, summary of study characteristics and findings, and assessment of study quality and risk of bias. I also discuss some hypothesized mechanisms for identified risk factors and make recommendations for future areas of research. A large proportion of the work in this chapter has been published in the journal Sports Medicine – Open (Spencer, Dickinson and Forbes 2018).

As discussed in chapter 1, the absence of a formal case definition for SIPE makes it more difficult to identify cases. Furthermore, the pathophysiology of SIPE is not well understood so it is not clear if it should be regarded as a chronic condition for which an individual is susceptible due to an underlying physiological issue, or a condition that can happen to anyone at any time. It is possible to draw on the similarities between SIPE and other conditions such as asthma, which can be regarded as chronic conditions with acute attacks.

Prevalence of a disease means the proportion of a population that are cases at a specific point in time. Asthma prevalence refers to the proportion of the population who have been diagnosed with asthma, many of whom are completely well most of the time without any symptoms at all. In these situations, it is necessary to “challenge” the asthma sufferer in order to trigger an attack, for example through exercise or exposure to an allergen. On the other hand, SIPE could be conceptualised as an acute condition such as the common cold where people experience many infections in a lifetime. In this sense we would not talk about prevalence of the common cold, but we may refer to the lifetime prevalence of ever having experienced a cold i.e. 100%. In this systematic review, I use the term prevalence to mean the number of swimmers who report having ever experienced an episode of SIPE as a percentage of all swimmers surveyed.

The incidence of disease is usually described over a year of exposure i.e. new cases of cancer diagnosed annually, however, in cases of SIPE, individuals are only exposed to the risk of developing the condition over relatively short periods of time; during or shortly after swimming. The risk is eliminated outside of these periods. Therefore, incidence in this context refers to the number of episodes of SIPE that occurred, or the number swimmers that experienced at least one episode of SIPE, over a specified time period, as a proportion of all swims or swimmers respectively. In this review, the time period refers to the duration of outdoor swimming races, time trials or group swims.

Risk factors are characteristics or exposures that precede and are associated with an occurrence of SIPE. They can be categorised into non-modifiable risk factors, modifiable risk factors and comorbidities. Modifiable risk factors are those that can be controlled or changed e.g. hypertension and fish oil supplement use, whereas non-modifiable risk factors are intrinsic to a person and cannot be controlled e.g. female sex, and lower lung volumes and flows.

The aim of this systematic review was to synthesise the epidemiological evidence about SIPE in open water swimmers to inform advice on risk of SIPE, implications of the diagnosis, and prevention of episodes and recurrences. The following research questions were addressed:

1. What is the incidence of SIPE?
2. What is the prevalence of having experienced SIPE?
3. What are the risk factors for SIPE?
4. What are the short-term outcomes of SIPE i.e. hospitalisation, death, recovery?
5. What is the recurrence rate of SIPE?
6. What are the long-term health sequelae of an episode of SIPE?

7. What is the evidence of the effectiveness of interventions for preventing a recurrence of SIPE?

3.2 Methods

3.2.1 Study selection criteria

I included original articles and conference abstracts (where there was no full paper reporting the same data) studying human subjects that provided data to answer one or more of the research questions. Conference abstracts were included due to the small number of relevant full text articles. Initially, all abstracts that mentioned immersion pulmonary oedema (IPE) were sought. These were then screened to remove articles that were not relevant. For the remaining studies, full text articles, where available, were sought. I then assessed these articles and abstracts according to the inclusion criteria shown in Table 2.

3.2.2 Search strategy

The literature search was carried out in two stages. The first stage took place in March 2018 and involved online searches of the MEDLINE, EMBASE and HMIC databases using Ovid online to identify peer reviewed publications and conference abstracts (see Table 3 for search strategy). Additional relevant studies were sought through The Rubicon Foundation[1], Mendeley, EThOS[2] and reference lists of review papers. No date parameters were included in the search. The second stage took place in April 2024 and involved a supplementary search for literature published from 2018 onwards using Ovid online and Web of Science, and search strategies in Tables 4 and 5 respectively.

[1] The Rubicon Foundation is a non-profit organisation interested in research, exploration, science and education, which hosts a digital repository of diving and environmental physiology research.
[2] Electronic Theses Online Service

Table 2: Inclusion criteria

Population:	Surface swimmers of any age swimming in pools or open water of any temperature. Excluding scuba or breath-hold (apnoea) divers.
Case definition:	Clinical diagnosis of SIPE or symptoms suggestive of SIPE (acute onset of SOB during swimming, with or without cough, with or without sputum production, in the absence of water aspiration). Care was taken to differentiate SIPE from other causes of acute breathlessness; most commonly asthma, cold shock response, left ventricular failure, pulmonary embolism and pneumonia.
Study design:	*Incidence:* Studies which identified a population of people at risk and followed them up to identify whether they developed SIPE.
	Prevalence: Cross-sectional studies carried out at a single point in time or over a defined period of time, in which cases of SIPE were sought using a consistent case definition.
	Risk factors: Cohort or case-control studies of people who had experienced SIPE and a comparator group of swimmers with no history of SIPE or symptoms suggestive of SIPE, where number of cases ≥8. This number was selected due to the low likelihood of finding statistical associations with <8 cases, and in an effort to ensure that not all studies were excluded. Exposures included personal characteristics such as age, sex, body mass index, body fat, medical history, medication, smoking etc. or environmental factors such as water temperature, weather conditions, clothing worn e.g. wetsuit, dive jacket, swimsuit etc.
	Prognosis: Any studies that included a group of patients that met the case definition and short (i.e. within 30 days) or long term outcomes were reported. Short term outcomes of interest included medical treatment, hospitalisation, length of time to recovery, or death. Long term outcomes of interest included recurrence of SIPE and long term sequelae.
	Interventions: Any studies of interventions for the prevention of SIPE recurrences, including case reports.

SOB = shortness of breath

Table 3: Search strategy using Ovid online in April 2018

Search number	Search terms
1	(immersion or submersion or swim* or diver or divers or diving or triath* or scuba).af.ab.dm.dv.fx.kw.mf.nm.ot.px.rx.sy.ti.tn.ui.
2	(pulmonary adj (oedema or edema)).af.ab.dm.dv.fx.kw.mf.nm.ot.px.rx.sy.ti.tn.ui.
3	1 and 2
4	Remove duplicates from 3

Table 4: Search strategy using Ovid online in April 2024

Search number	Search terms
1	(immersion or submersion or swim* or diver or divers or diving or triath* or scuba).af.ab.dm.dv.fx.kw.mf.nm.ot.px.rx.sy.ti.tn.ui.
2	(pulmonary adj (oedema or edema)).af.ab.dm.dv.fx.kw.mf.nm.ot.px.rx.sy.ti.tn.ui.
3	1 and 2
4	Limit 3 to yr="2018 – 2024"
5	Remove duplicates from 4

Table 5: Search strategy using Web of Science in April 2024

Search terms
immersion or submersion or swim* or diver or divers or diving or triath* or scuba
And: pulmonary adj (oedema or edema)
And Year Published: 2018-2024

3.2.3 Data extraction and assessment of study quality

Data were extracted using data extraction forms shown in Appendix 2. Risk of bias was assessed by adapting quality assessment tools developed by the National Heart Lung and Blood Institute (NHLBI 2014), Hoy *et al.*, (2012) and Downs and Black (1998).

3.3 Results

Overall, the search strategy identified a total of 570 titles and abstracts after duplicates were removed, of which 297 were relevant. Initial inclusion criteria were applied to these records, which resulted in the exclusion of 281 studies. Of the remaining 16 studies, 14 met the inclusion criteria for individual research questions (see PRISMA flowchart in Figure 1).

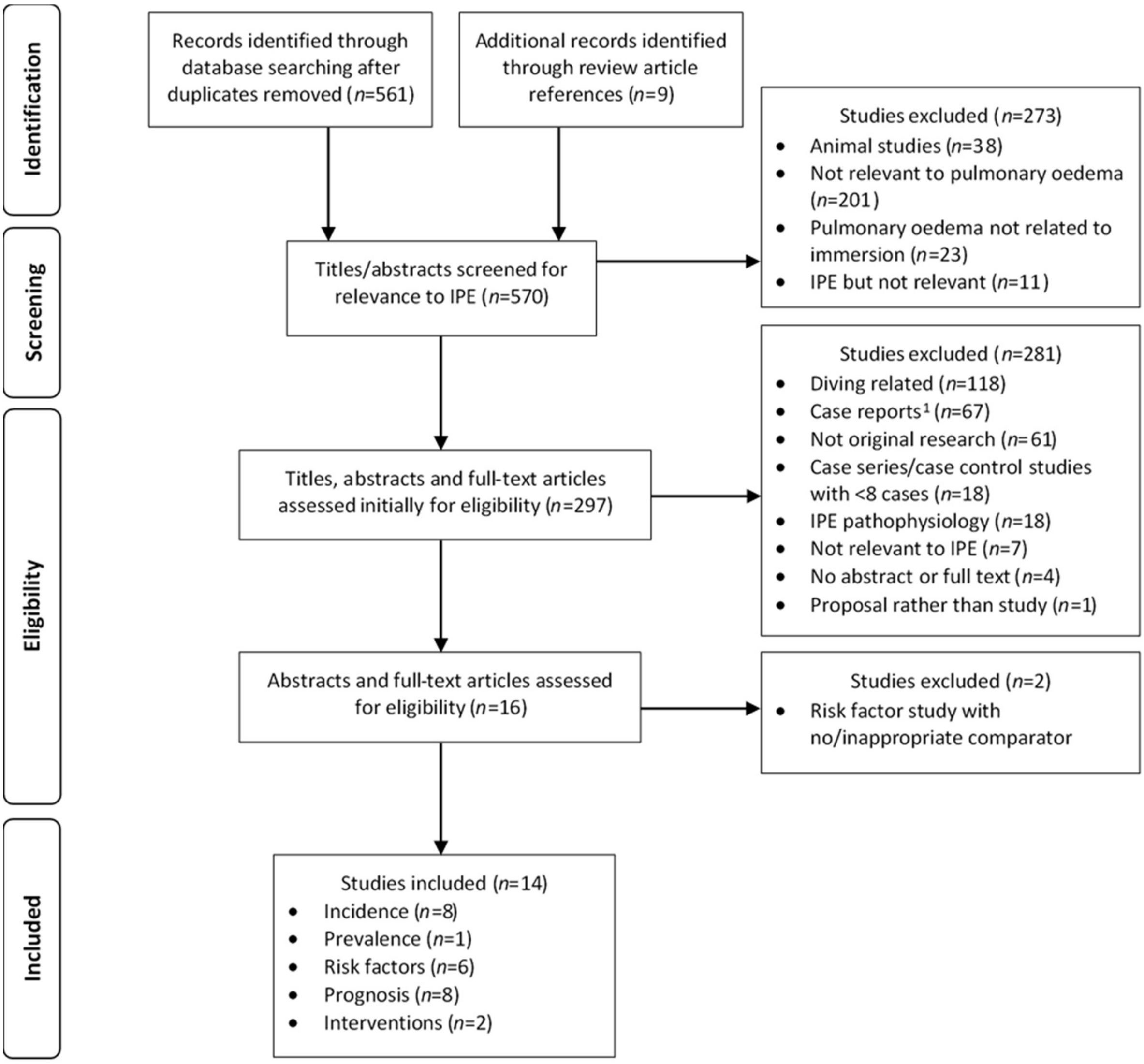

Figure 1: PRISMA flow diagram of study screening and selection (Moher et al. 2009). [1] *One case report was included in the interventions section due to a lack of relevant studies. Note: Numbers do not add up because some studies addressed more than one research question.*

3.3.1 What is the incidence of SIPE?

3.3.1.1 Description of studies

Eight incidence studies met the inclusion criteria; three of young male Israeli military trainees aged 18–19 carrying out 2.4–3.6 km swimming time trials in the open sea (Adir *et al.* 2004; Shupak *et al.* 2000; Weiler-Ravell *et al.* 1995), two of young US Navy SEAL trainees undertaking a variety of open water swims (Volk *et al.* 2021; Sebreros *et al.* 2023), one of competitors of 1–3km swimming races in two Swedish rivers (Hårdstedt *et al.* 2021), one of triathletes competing in UK triathlons with a 0.4–1.5km swim (Smith *et al.* 2017), and one Australian study of 20 trained long-distance open water swimmers taking part in an eight hour swim (Lindqvist *et al.* 2022) (see Tables 6 and 7). The five studies of military trainees took place over a period of one day, two months, three years, 15 months, and 12 months (Weiler-Ravell *et al.*, 1995; Shupak *et al.*, 2000; Adir *et al.*, 2004; Volk *et al.*, 2021 and Sebreros *et al.*, 2023 respectively). Hårdstedt *et al.* (2021) carried out their study at the annual Vansbrosimningen open water swimming event over four consecutive years. Smith *et al.* (2017) investigated the competitors of 11 UK triathlon events that took place over five years, and Lindqvist *et al.* (2022) studied 20 open water swimmers during a single eight hour long distance swim. Sample sizes of included studies ranged from 20 individuals (Lindqvist *et al.* 2022) to almost 47,600 swimming distances (Hårdstedt *et al.* 2021). One additional study of open water swimmers (Braman Eriksson, Annsberg and Hardstedt 2017) was excluded because the sample was a subset of the larger sample used by Hårdstedt *et al.* (2021). Two studies of divers were excluded; one of rebreather[3] incidents in French military divers (Gempp *et al.* 2011) and one of Basic Underwater Demolition/SEAL trainees at US dive training facilities (Keuski 2011).

3.3.1.2 Case ascertainment method

In all but two studies (Shupak *et al.*, 2000 and Lindqvist *et al.*, 2022), cases of SIPE were identified from swimmers that sought medical attention. Shupak *et al.* (2000) required all trainees, symptomatic or not, to complete post-swim questionnaires, and categorised cases into mild cases where the swimmer was able to complete the swim and severe cases where the swim had to be

[3] Rebreathers absorb the carbon dioxide exhaled by a diver whilst recycling the unused oxygen content and replenishing it for the next breath.

stopped. Lindqvist *et al.* (2022) carried out lung ultrasound scans of all swimmers when they exited the water and asked them to rate their breathlessness.

3.3.1.3 Definition of SIPE

The studies used varying case definitions for SIPE, which are described in Tables 6 and 7. Different methods were used for calculating the rate of incidence. For example, some authors counted swimmers that experienced at least one episode of SIPE and used the total number of swimmers as the denominator (Weiler-Ravell *et al.* 1995; Shupak *et al.* 2000; Sebreros *et al.* 2023; Volk *et al.* 2021; Lindqvist *et al.* 2022), whereas others counted the number of episodes of SIPE and used the total number of swims as the denominator (Smith *et al.* 2017; Hårdstedt *et al.* 2021; Adir *et al.* 2004).

3.3.1.4 Quality of studies

Six studies had a clearly specified and defined population of swimmers (Adir *et al.* 2004; Shupak *et al.* 2000; Weiler-Ravell *et al.* 1995; Sebreros *et al.* 2023; Volk *et al.* 2021; Hårdstedt *et al.* 2021); the remaining two contained no demographic information on the at risk population (Smith *et al.* 2017; Lindqvist *et al.* 2022). Inclusion and exclusion criteria were documented in all studies apart from Weiler-Ravell *et al.* (1995), Shupak *et al.* (2000), Smith *et al.* (2017) and Lindqvist *et al.* (2022). SIPE case definitions were mostly clearly described although they varied considerably and the denominator used to calculate incidence varied, making the results difficult to compare reliably (see 3.3.1.3).

In none of the studies were the cases censored in all the subsequent analyses. This means that cases that were included in initial analyses were not excluded from all subsequent analyses. This is not a problem for studies that measured incidence by the number of SIPE episodes that occurred over the time period. However, for studies that measured incidence by the number of swimmers that experienced at least one episode of SIPE, it can lead to inflated incidence estimates. Hårdstedt *et al.*

(2021) accounted for cases only once for each year of the event, however, individuals were included multiple times in the data if they were identified as a case in more than one year of the event.

As mentioned earlier, Shupak *et al.* (2000) and Lindqvist *et al.* (2022) were the only studies that collected data from *all* participants rather than just those that sought medical attention, making it possible to identify milder cases of SIPE where the swimmer was able to complete their swim. For full results of the risk of bias assessment, please see Appendix 3a.

3.3.1.5 Findings

Quantitative synthesis was not possible due to the heterogeneous nature of the studies, in particular, the military trainees in five studies were young men engaged in rigorous training programmes, whereas the UK and Swedish studies included recreational swimmers of all ages and both sexes (Smith *et al.*, 2017; Hårdstedt *et al.,* 2021). It is unclear what type of open water swimmers were the subject of the Lindqvist *et al.* (2022) study. Incidence figures for SIPE among Israeli military trainees included 1.8% (*n*=70), 16.6% (*n*=29) and 26.7% (*n*=8) of swimming time trials performed in the open sea (Adir *et al.* 2004; Shupak *et al.* 2000; Weiler-Ravell *et al.* 1995) (where *n*=number of SIPE cases). For Navy SEAL candidates, the incidence of SIPE was 4.3% (*n*=45) and 5.0% (*n*=106) of the cohort (Sebreros *et al.* 2023; Volk *et al.* 2021). Other incidence figures reported included 0.01% (*n*=5) of triathlons raced in the UK (Smith *et al.* 2017), 0.44% (*n*=211) of outdoor swimming races started at the Swedish event (Hårdstedt *et al.* 2021), and 25.0% (*n=5*) of trained long-distance open water swimmers (Lindqvist *et al.* 2022). Of the 29 episodes of SIPE recorded by Shupak *et al.* (2000), eight were categorised as severe cases and 21 as mild, which is equivalent to 4.6% and 12.0% of swimming trials performed respectively.

3.3.2 What is the prevalence of having experienced SIPE?

3.3.2.1 Description of studies

Four cross-sectional surveys were identified, however, only one was of surface swimmers. This was a large survey of triathletes in the US (see Table 7) (Miller, Calder-Becker and Modave 2010). The remaining studies were of scuba divers (Pons *et al.* 1995) and breath-hold divers (Cialoni *et al.* 2012; Cialoni *et al.* 2014) so were excluded from the review. Miller, Calder-Becker and Modave (2010) distributed a swim related breathing problems survey to 140,000 USA Triathlon members and received 1,400 valid responses.

3.3.2.2 Definition of SIPE

The case definition used by Miller, Calder-Becker and Modave (2010) was limited to a cough productive of pink frothy or blood-tinged secretions during swimming. Information on the type of exposure was collected, such as open water versus pool environment, use of a wetsuit, course length and climate.

3.3.2.3 Quality of studies

Miller, Calder-Becker and Modave (2010) carried out a large study with a strong design, providing a detailed description of the sampling frame and methodology. The demographics of the sample appeared representative of USA Triathlon members. The analysis was robust and used appropriate numerators and denominators. However, the response rate was very low at 1.3% and data were collected through a non-validated self-completed questionnaire. For full results of the risk of bias assessment, please see Appendix 3b.

3.3.2.4 Findings

Miller, Calder-Becker and Modave (2010) reported a prevalence of symptoms consistent with SIPE of 1.4% of triathletes.

3.3.3 What are the risk factors for SIPE?

3.3.3.1 Description of studies

Five studies met the inclusion criteria; two prospective cohort studies of military trainees (Shupak *et al.*, 2000; Sebreros *et al.*, 2023), a case-control study of triathletes in the US (Miller, Calder-Becker and Modave 2010), a study of competitive and recreational swimmers in an annual Swedish open water swimming event (Hårdstedt *et al.* 2021), and a small clinical trial involving 10 SIPE susceptible individuals (Moon, Martina, Peacher, Potter, *et al.* 2016) (see Tables 6 and 7). An additional 11 studies that addressed risk factors were identified, but were excluded due to not meeting the inclusion criteria. This included studies of scuba divers (Wilmshurst *et al.* 1981; Wilmshurst *et al.* 1989; Castagna *et al.* 2018; Castagna *et al.* 2023; Henckes *et al.* 2019; Edmonds, Lippman and Bove 2019), a very small sample size (Wilmshurst *et al.* 1981), the lack of a control or comparator group (Adir *et al.* 2004; Peacher *et al.* 2015; Volk *et al.* 2021; Braman Eriksson, Annsberg and Hardstedt 2017) or the use of an inappropriate comparator group (Moon, Martina, Peacher and Kraus 2016). The latter study included a comparator group that consisted of participants of the 1985 and 1995 Hawaii Ironman World Championships, who I deemed unrepresentative of the overall triathlete population.

Miller, Calder-Becker and Modave (2010) used the responses from their large survey of USA Triathlon members aged ≥20 (85% were aged ≥30) augmented by 11 cases identified through slowtwitch.com (an online triathlon discussion forum), to reach a sample size of 1,411 cases. The two studies of military trainees included Sebreros *et al.* (2023), who investigated 113 young male US Navy SEAL candidates (mean age of 24) starting their training, and Shupak *et al.* (2000) who researched 35 Israeli military trainees (males aged 18-19) carrying out swimming time trials over a two month period. Hårdstedt *et al.* (2021) studied 47,573 competitors of the Vansbrosimningen open water swimming event over four consecutive years. Moon, Martina, Peacher, Potter, *et al.* (2016) studied 30 healthy participants, of whom 10 had experienced ≥1 episode of SIPE during diving (two subjects), racing or training for a triathlon (five subjects), both (two subjects) or after falling from a windsurfer (one subject). Study participants carried out moderate cycle ergometer exercise for six to seven minutes whilst submerged in water of 20°C. All of the SIPE subjects then repeated the exercise following an oral dose of 50mg sildenafil. Measurements of mean arterial pressure (MAP), mean pulmonary artery pressure (MPAP) and pulmonary artery wedge pressure (PAWP) were taken before immersion, during immersed exercise and shortly afterward. The types of exposure identified by Miller, Calder-Becker and Modave (2010), Hårdstedt *et al.* (2021), Sebreros *et al.* (2023) and Moon, Martina, Peacher, Potter, *et al.* (2016) were varied in terms of personal and/or environmental factors, whereas the participants of the Shupak *et al.* (2000) study were all young men swimming in moderately cold open sea (16-18°C), wearing diving jackets and fins, and swimming in the supine position.

3.3.3.2 Definition of SIPE

Case definitions in Miller, Calder-Becker and Modave (2010) and Shupak *et al.* (2000) included a cough, however, Miller, Calder-Becker and Modave (2010) incorporated pink frothy or blood-tinged secretions, whereas Shupak *et al.* (2000) specified shortness of breath and lack of aspiration of seawater. Sebreros *et al.* (2023) did not include a cough in their case definition, but did include SOB and frothy/blood-tinged sputum, and required the presence of chest crackles or oxygen saturation <95%, during or after intense exertion in water, as well as pulmonary oedema on chest x-ray, and symptoms and signs that improved within 48 hours. The case definition used by Hårdstedt *et al.* (2020) included SOB and/or cough with additional criteria that varied according to the year of the swimming event. In 2016 the authors included chest crackles *and* low oxygen saturation, in 2017 they included chest crackles *or* oxygen saturation ≤95%, and in 2018 and 2019 they included pulmonary oedema on lung ultrasound scan (LUS), or in the absence of an LUS, they used the 2017 case definition. Moon, Martina, Peacher, Potter, *et al.* (2016) did not report a case definition for SIPE.

3.3.3.3 Quality of studies

Miller, Calder-Becker and Modave (2010) reported good representation in terms of age and sex of participants and studied a wide range of risk factors. Hårdstedt *et al.* (2021) investigated age and sex as risk factors, using a very large sample of 47,573 races swum by 45,913 competitors, with a fairly equal split of males and females, ranging in age from 18 to over 60. Risk factors examined in the two studies of military trainees included pulmonary function and self-reported level of exertion (Shupak *et al.* 2000), and respiratory infections (Sebreros *et al.* 2023). Moon, Martina, Peacher, Potter, *et al.* (2016) focussed on haemodynamics and gas exchange measurements.

A weakness of Miller, Calder-Becker and Modave (2010) and Shupak *et al.* (2000) was the use of a self-reported non-validated questionnaire to detect cases of SIPE. In their multivariate analyses of data collected from respondents aged 20 to over 70, Miller, Calder-Becker and Modave (2010) did not adjust for age. Miller, Calder-Becker and Modave (2010) included questions on health conditions such as hypertension and diabetes in their questionnaire, however, it is not clear when diagnosis took place i.e. before or after SIPE occurred, or if any medications were being taken. There is some evidence that self-reports may underestimate the prevalence of hypertension (Goldman *et al.* 2003), although some studies have shown these to be a valid measure (Giles *et al.* 1995; Vargas *et al.* 1997).

Hårdstedt *et al.* (2020) had the advantage of a very large sample size, however, other than age and sex, the authors did not collect any data from controls i.e. swimmers who did not seek medical attention. Therefore, they were not able to adjust for any confounding factors such as health conditions, and may have missed some milder cases of SIPE where competitors did not seek medical attention. Sebreros *et al.* (2023) treated their control group differently to cases, which increased the risk of selection bias i.e. the authors used different respiratory pathogen tests, the data were collected over two days in May compared to the 12 month period for cases, and controls had not been undergoing strenuous swimming before the tests, unlike cases (although the authors state that no controls had been diagnosed or suspected of experiencing SIPE previously). In particular, the lack of testing of controls over the winter season, when outbreaks of many respiratory viruses are known to occur (Neumann and Kawaoka 2022) means that the exposure of controls to many viruses would most likely have been lower than cases. Moon, Martina, Peacher, Potter, *et al.* (2016) also acknowledged differences between their case and controls groups i.e. the SIPE group contained a much higher proportion of females than the control group and may have been physically fitter. There were also differences in the criteria used for selecting cases and controls. Appendix 3c shows full results of the quality assessment.

Some studies lacked the statistical power needed to detect significant relationships and differences between groups due to relatively small sample sizes used. For example Miller, Calder-Becker and Modave (2010) reported ORs of >2 for nine risk factors, however, p-values were low enough in only four of them to demonstrate statistical significance. Sebreros *et al.* (2023) also lacked statistical power, with a risk factor sample size of just 113 trainees, and the authors used the chi-square test in their analyses, rather than calculating odds ratios (ORs), which does not tell us anything about the strength of the association.

3.3.3.4 Findings

The populations studied by Miller, Calder-Becker and Modave (2010), Moon, Martina, Peacher, Potter, *et al.* (2016) and Hårdstedt *et al.* (2021) were much more heterogeneous compared to Shupak *et al.* (2000) and Sebreros *et al.* (2023) i.e. male and females of varying ages versus young healthy male military recruits on rigorous training programmes. Therefore, I did not attempt quantitative synthesis. Miller, Calder-Becker and Modave (2010) showed the following risk factors to be associated with developing SIPE: hypertension, female sex, fish oil use and long course distance (i.e. ≥ half-ironman distance: 1.9km swim, 90km bike ride and 21.1km run). Hårdstedt *et al.* (2021) found female sex and age >30 to be significant risk factors, with ORs increasing with age. Sebreros *et al.* (2023) reported that cases were more likely to test positive for respiratory pathogens than controls, and Shupak *et al.* (2000) discovered that lung volumes and mid-expiratory flow measured

12 months earlier were significantly lower in those who had experienced SIPE compared to the asymptomatic group. Shupak *et al.* (2000) also reported no correlations between level of exertion and occurrence of SIPE. The results of Moon, Martina, Peacher, Potter, *et al.* (2016) showed that the SIPE group had significantly higher MPAP and PAWP than the non-SIPE group during immersed exercise, when accounting for differences in cardiac output. Tidal volume was also significantly lower in the SIPE group.

3.3.4 Prognosis

The following research questions regarding prognosis were addressed:

1. What are the short term outcomes of SIPE?
2. What is the recurrence rate of SIPE?
3. What are the long term health sequelae of an episode of SIPE?

I considered short term outcomes to be those that occurred <30 days after an episode of SIPE, such as recovery time, hospitalisation and death. Long term health sequelae were considered to be those which occurred ≥30 days following an episode.

3.3.4.1 Description of studies

Nine studies met the inclusion criteria; three of Israeli military trainees (Adir *et al.* 2004; Shupak *et al.* 2000; Weiler-Ravell *et al.* 1995) (described in section 3.3.1), three of US Navy SEAL candidates (Ludwig *et al.* 2006; Sebreros *et al.* 2023; Volk *et al.* 2021), two of competitors of an outdoor swimming event in Sweden (Kristiansson *et al.* 2023; Braman Eriksson, Annsberg and Hardstedt 2017) (described in section 3.3.1) and one of three triathletes who took part in an extreme triathlon in Norway (Melau *et al.* 2019). Ludwig *et al.* (2006) studied a group of 20 males aged 19–36, 11 of whom had recovered from an episode of SIPE 4–14 weeks before the study commenced.

3.3.4.2 Definition of SIPE

Case definitions are described in Tables 6 and 7. Ludwig *et al.* (2006) had more rigorous requirements for a SIPE diagnosis to be made compared to the other studies (see Table 7). In all studies, SIPE cases were ascertained through swimmers receiving medical attention, apart from Shupak *et al.* (2000) who required all trainees to complete post-swim questionnaires.

Seven studies reported short term outcomes such as recovery time (Adir *et al.* 2004; Weiler-Ravell *et al.* 1995; Kristiansson *et al.* 2023; Braman Eriksson, Annsberg and Hardstedt 2017; Melau *et al.* 2019) and hospitalisation (Weiler-Ravell *et al.* 1995; Kristiansson *et al.* 2023; Volk *et al.* 2021; Sebreros *et al.* 2023; Melau *et al.* 2019). I found no studies that reported any deaths following SIPE. Adir *et al.* (2004) carried out chest radiographs 12–18 hours after the onset of SIPE symptoms. They also performed spirometry on a subsample of 37 trainees 6–12 hours and one week after diagnosis of SIPE, and compared findings with baseline measurements.

Six studies provided data on recurrences, however, this was reported in different ways: Shupak *et al.* (2000), Adir *et al.* (2004), Volk *et al.* (2021), Kristiansson *et al.* (2023) and Sebreros *et al.* (2023) reported recurrences of SIPE episodes that occurred during the study period (i.e. 2 months, 3 years, 15 months, 30 months and 12 months respectively) whereas Weiler-Ravell *et al.* (1995) reported recurrences that took place at unspecified times later within the same training programme, but outside the study period.

Longer term outcomes were investigated in only two studies; Ludwig *et al.* (2006) and Kristiansson *et al.* (2023). The SIPE subjects studied by Ludwig *et al.*, (2006) had all fully recovered from SIPE at least one month before enrolment in the study. The authors examined cardiopulmonary function (exercise tolerance, lung volumes and flows, pulmonary artery pressure response to hypoxemia) at 4–14 weeks after SIPE. Kristiansson *et al.* (2023) followed up cases at 30 months and asked questions about symptom duration.

3.3.4.3 Quality of studies

Apart from Kristiansson *et al.* (2023), the studies were not designed as prognosis studies, and it was difficult to make comparisons between them because of differences in the outcomes described and the way in which they were reported. The characteristics of study participants were clearly defined in all prognosis studies except Braman Eriksson, Annsberg and Hardstedt (2017). Although sample sizes were small in some of the studies of military trainees e.g. Weiler-Ravell *et al.* (1995), Shupak *et al.* (2000) and Ludwig *et al.* (2006), they are likely to be representative of the military populations in terms of age and gender. The small sample size of three used by Melau *et al.* (2019), which included one professional triathlete, is unlikely to be representative of the general triathlete population. The representativeness of the participants of Braman Eriksson, Annsberg and Hardstedt (2017) and Kristiansson *et al.* (2023) is unclear as no demographic information on the at risk populations were reported. The questionnaire used by Kristiansson *et al.* (2023) in follow up interviews was not fully validated, however, the authors state there was an opportunity to clarify questions and answers during the interviews. The study was also limited by the use of inconsistent case definitions between different years of the event and between the 20 day and 30 month follow ups. For full results of the critical appraisal of these studies, please see Appendix 3d.

3.3.4.4 Findings

Four of the studies that reported recovery time following SIPE found that all affected swimmers recovered from SIPE symptoms within 24 hours (Adir *et al.* 2004; Weiler-Ravell *et al.* 1995; Braman Eriksson, Annsberg and Hardstedt 2017; Melau *et al.* 2019). Kristiansson *et al.* (2023), however, found that 15–21% of cases had experienced symptoms lasting for more than five days. Adir *et al.* (2004) reported that chest radiographs were all normal in the first 24 hours, although the subsample of 37 trainees who had spirometry showed reduced lung volumes that persisted for a week. Hospital stays following SIPE were reported by 2%, 7%, and 4% of cases detected by Volk *et al.* (2021), Kristiansson *et al.* (2023) and Sebreros *et al.* (2023) respectively. All eight swimmers observed by

Weiler-Ravell *et al.* (1995) that experienced SIPE were admitted to hospital overnight. Two of the three triathletes included in the Melau *et al.* (2019) study stayed in hospital for one night.

Reported recurrence rates in affected military trainees were; 23% within 3–36 months after their first episode (Adir *et al.* 2004), 9% within 12 months (Sebreros *et al.* 2023), 9% within 15 months (Volk *et al.* 2021) and 25% at an unspecified time during the remainder of the training programme (Weiler-Ravell *et al.* 1995). Shupak *et al.* (2000) found that nine of the 29 episodes that occurred during the two month study period were recurrences of observed episodes.

In their study of longer term outcomes, Ludwig *et al.* (2006) found no significant differences in cardiopulmonary function between SIPE patients and controls 4–14 weeks after the episode. Kristiansson *et al.* (2023) followed up cases at 30 months and found that six patients (4%) had experienced SIPE symptoms for over 12 months.

Table 6: Summary of studies investigating occurrence, risk factors and/or prognosis of SIPE (June 2017 to November 2023)

Authors	**Kristiansson *et al.* (2023)**	**Sebreros *et al.* (2023)**	**Lindqvist *et al.* (2022)**	**Hårdstedt *et al.* (2021)**	**Volk *et al.* (2021)**	**Melau *et al.* (2019)**	**Braman Eriksson, Annsberg and Hardstedt (2017)**
Study design	Outcomes study	Prospective incidence and case-control study of risk factors	Prospective incidence study	Prospective incidence and case-control study of risk factors	Prospective incidence study	Prospective incidence study	Prospective incidence study
Participants	Competitive and recreational adult swimmers in Swedish open water swimming events 2017-2019	Military trainees, with mean age of 24, starting US Navy SEAL training in Dec 2020-Nov 2021	Trained long-distance open-water swimmers who took part in an 8 hour open water swim	Competitive and recreational adult swimmers in Swedish open water swimming events 2016-2019	Military trainees with mean age of 23, in US Navy SEAL training within a 15 month period Feb 2018-Apr 2019	Competitors of Extreme triathlon in Norway 2016-2018. Two males and one female aged 30, 34 and 40 respectively	Competitive and recreational swimmers aged 12-70 in Swedish open water swimming event in 2016
Type of exposure	1-3km river races in water of 15-20°C	No detail on type of open water, a variety of types of swims, some up to 2 miles and some during an intensive 5 days of exertions. Unclear if wetsuits worn	Exposure time of 8 hours. No further details	1-3km river races in water of 16-20°C. Wetsuit use reported for SIPE cases only	Included 2 mile ocean swims, prolonged water treading and Hell Week[1] activities in water of 14-26°C. Exposure time at different water temperatures measured in person-days. Unclear if wetsuits worn	2.4 mile fjord swim in water of 14-18°C. Athletes wore wetsuits and neoprene swim caps	1-3km river races in water of approx. 17°C. Wetsuit use unknown
Case definition	SOB and/or cough and (chest crackles and/or oxygen saturation ≤95%) or (pulmonary oedema on LUS, if performed)	SOB and blood in sputum during or shortly after swim, and chest crackles or oxygen saturation <95%, and chest x-ray showed pulmonary oedema, and improvement of symptoms and signs within 48 hours	SOB and pulmonary oedema on LUS	2016: SOB and/or cough, chest crackles and low oxygen saturation; 2017: SOB and/or cough, and chest crackles or oxygen saturation ≤95%; 2018 and 2019: SOB and/or cough, and pulmonary oedema on LUS	Respiratory symptoms, and frothy or bloody sputum, and (pulmonary oedema on chest x-ray or symptoms that resolved within 24 hours)	SOB, chest tightness and pink sputum	No standard definition. Examining physicians identified cases without a formal case definition

Authors	Kristiansson *et al.* (2023)	Sebreros *et al.* (2023)	Lindqvist *et al.* (2022)	Hårdstedt *et al.* (2021)	Volk *et al.* (2021)	Melau *et al.* (2019)	Braman Eriksson, Annsberg and Hardstedt (2017)
Case ascertainment method	Clinical presentation at the event	Those who sought medical help	All swimmers underwent an LUS and rated their SOB upon leaving the water	Those who sought medical care at the event	Retrospective diagnosis by 2 chest physicians using clinical data and chest x-rays of swimmers who sought medical attention	Clinical presentation at the event	Clinical examination of competitors presenting to medical team
Occurrence							
Sample size	N/A	1,048 military trainees	20 open-water swimmers (10 males)	47,573 swimming distances	2,117 military trainees	N/A	N/A
Incidence reported (*n*=SIPE cases)	N/A	4.3% (*n*=45) of cohort	25.0% (*n*=5) of cohort	0.44% (*n*=211) of swims started by competitors	5.0% (*n*=106) of cohort had definite or probable SIPE	N/A	N/A
Prevalence reported (*n*=SIPE cases)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Risk factors							
Sample size	N/A	113 trainees (45 cases, 68 controls)	N/A	47,573 swimmers (211 cases, 47,362 controls)	N/A	N/A	N/A
Exposures investigated	N/A	Presence of respiratory viruses or bacteria detected on nasopharyngeal swab	N/A	Age, sex	N/A	N/A	N/A
Findings	N/A	Cases were more likely to test positive for a respiratory virus or bacteria than controls. ORs not reported	N/A	Significant risk factors were female sex and age >30, with ORs increasing with age	N/A	N/A	N/A

Authors	Kristiansson *et al.* (2023)	Sebreros *et al.* (2023)	Lindqvist *et al.* (2022)	Hårdstedt *et al.* (2021)	Volk *et al.* (2021)	Melau *et al.* (2019)	Braman Eriksson, Annsberg and Hardstedt (2017)
Prognosis							
Size of sample followed up	165 patients	45 cases	N/A	N/A	106 cases	3 cases	Approx. 69 cases
Period of follow up	At 10 days and 30 months	12 months	N/A	N/A	15 months	1 day (3 cases) and 1 month (1 case)	N/A
Short term outcomes	15-21% had symptoms lasting >5 days. 12 (7%) cases were admitted to hospital, including 4 to ICU. Length of stay for these 12 people was ≤3 days.	Two cases hospitalized for short time, one in ICU	N/A	N/A	Two cases admitted to ICU but recovered rapidly	Two cases admitted to hospital and recovered the next day. One taken to local medical centre, treated with oxygen, and recovered quickly	All recovered following treatment on site.
Recurrence	At 30 months, 28% had had a recurrent episode of SIPE.	4 cases had a recurrence of an observed episode.	N/A	N/A	10 cases had a recurrence at least several weeks after initial episode.	Not reported	N/A
Long term health sequalae	6 patients (4%) said symptoms lasted >12 months.	Not reported	N/A	N/A	Not reported	Not reported	Not reported

Authors	Kristiansson *et al.* (2023)	Sebreros *et al.* (2023)	Lindqvist *et al.* (2022)	Hårdstedt *et al.* (2021)	Volk *et al.* (2021)	Melau *et al.* (2019)	Braman Eriksson, Annsberg and Hardstedt (2017)
Quality of evidence							
Summary	Case definition not consistent between years and 10 day and 30 month follow-ups. Recurrences were not verified by clinical examinations or radiology. Questionnaire used in follow-ups was not fully validated. Risk of recall and self-reporting bias in follow-up interviews	Milder cases of SIPE may have been missed if trainee did not seek medical attention. High dropout rate among trainees. Data collection periods and tests used to detect RPs for cases and controls were different. Interval between first episode and recurrence not reported. No follow-up after study period	Conference abstract, therefore limited detail. No information on demographics and type of swimmers or exposure.	Case definition was not consistent across years. Milder cases of SIPE may have been missed if swimmer did not seek medical attention.	Milder cases of SIPE may have been missed if trainee did not seek medical help. Follow-up chest x-ray not always possible. Study was low-powered. Unknown if first SIPE episode in study period was a recurrence. Time interval between first episode and recurrence only specified broadly as "several weeks". No follow-up after study period	Very small sample. Unlikely to be representative of the general triathlete population.	Data only collected for those requiring treatment. Symptoms and clinical findings were not recorded for each swimmer

ICU = Intensive Care Unit; LUS = lung ultrasound scan; ORs = odds ratios; SEAL = Sea, Air and Land; SOB = shortness of breath.

[1] Five days of intense exertion with almost no rest or sleep while frequently immersed and continuously wet and cold.

Table 7: Summary of studies investigating occurrence, risk factors and/or prognosis of SIPE (August 1995 to February 2017)

Authors	**Smith *et al.* (2017)**	**Moon, Martina, Peacher, Potter, *et al.* (2016)**	**Miller, Calder-Becker and Modave (2010)**	**Ludwig *et al.* (2006)**	**Adir *et al.* (2004)**	**Shupak *et al.* (2000)**	**Weiler-Ravell *et al.* (1995)**
Study design	Prospective incidence study	Clinical trial	Prevalence and case-control study	Case-control study	Prospective incidence study	Prospective incidence study	Prospective incidence study
Participants	Triathletes taking part in 11 triathlon events in the UK in 2011-2016.	Triathletes, divers and one windsurfer	Members of USA Triathlon (plus additional 11 cases from slowtwitch.com)	Military trainees (US Navy SEAL). Males aged 19-36 in first 5 weeks of 22 week training programme.	Military trainees (Israeli Navy). Males aged 18-19 in swimming trials in 1998-2001	Military trainees (Israeli Navy). Males aged 18-19 performing 5 swimming trials over 2 months (Jan-Mar)	Military trainees (Israeli Navy). Males aged 18-19 performing a single swimming trial
Type of exposure	Swimming distances of 400m, 750m and 1500m.	Varying	Varying	Not reported.	Open sea of 20°C, 2.4-3.6km distances (30-45 min duration), no wetsuits, supine semi-reclining position with fins	Open sea of 16-18°C, 2.4-3.6km distances, diving jackets worn, supine position with fins. Trials were ≥1 week apart.	Open sea of 23°C, 2.4km distance, no wetsuit, supine position with fins, trainees drank approx. 5 L water prior to swimming
Case definition	SOB, cough and/or frothy sputum, in absence of water aspiration, with evidence of pulmonary oedema on physical examination	No case definition provided	Cough and blood in sputum	SOB or blood in sputum during or immediately after swimming, in the absence of water aspiration, airway blockage by vocal cord spasm, or respiratory infections, and oxygen saturation <92% or alveolar-arterial oxygen gradient >30mm Hg, and pulmonary oedema on x-ray that resolved within 48 hours	Severe SOB and coughing during or after swimming in the absence of water aspiration, and evidence of pulmonary oedema on physical examination	SOB and cough in the absence of water aspiration	SOB and blood in sputum

Authors	Smith *et al.* (2017)	Moon, Martina, Peacher, Potter, *et al.* (2016)	Miller, Calder-Becker and Modave (2010)	Ludwig *et al.* (2006)	Adir *et al.* (2004)	Shupak *et al.* (2000)	Weiler-Ravell *et al.* (1995)
Case ascertainment method	Medical records of competitors presenting to medical team	Not reported	Questionnaire to all USA Triathlon members for prevalence study plus 11 additional cases from slowtwitch.com for risk factor study	Previous clinical diagnosis of a single episode of SIPE	Interview and clinical examination of swimmers presenting to medical team	All trainees were examined and completed post-swim questionnaire	Clinical examination of trainees presenting to medical team
Occurrence							
Sample size	68,557 triathlon races	N/A	1,400 after 23 exclusions due to age <20 years or incomplete responses	N/A	Approx. 3,900 swimming trials performed by unknown number of trainees	175 swimming trials performed by 35 trainees	30 trainees
Incidence reported (*n*=SIPE cases)	0.01% (*n*=5) of triathlons raced	N/A	N/A	N/A	1.8% (*n*=70) of swimming trials performed	16.6% (*n*=29) of 175 swimming trials by 21 swimmers: 8 severe cases (4.6%), 21 mild cases (12%)	26.7% (*n*=8) of swimmers in one trial
Prevalence reported (*n*=SIPE cases)	N/A	N/A	1.4% (*n*=20) of triathletes	N/A	N/A	N/A	N/A
Risk factors							
Sample size	N/A	30 participants: 22 males, 8 females (10 cases, 20 controls)	1,411 triathletes (31 cases, 1380 controls)	N/A	N/A	35 males (21 cases, 14 controls)	N/A

Authors	Smith *et al.* (2017)	Moon, Martina, Peacher, Potter, *et al.* (2016)	Miller, Calder-Becker and Modave (2010)	Ludwig *et al.* (2006)	Adir *et al.* (2004)	Shupak *et al.* (2000)	Weiler-Ravell *et al.* (1995)
Exposures investigated	N/A	Haemodynamics and gas exchange measurements	Age, sex, hypertension, diabetes, use of multivitamins, vitamin C, vitamin E, fish oil, flax oil. Swimming skill, warm up, pre-swim hydration, wetsuit use, climate trained in, open water/pool, course distance	N/A	N/A	Lung function, level of exertion	N/A
Findings	N/A	SIPE group had significantly higher MPAP and PAWP, and lower tidal volume during immersed exercise	Significant risk factors were hypertension, female sex, fish oil use and long course distance	N/A	N/A	Lung volume and mid-expiratory flow measured 12 months earlier were significantly lower in cases than controls. No association between exertion and SIPE	N/A
Prognosis							
Size of sample followed up	N/A	N/A	N/A	20 trainees (11 cases, 9 controls)	70 cases	21 trainees who had 29 episodes of SIPE	8 cases
Period of follow-up	N/A	N/A	N/A	4-14 weeks after recovery from SIPE	Within 3 year period	2 months	Until end of training programme

Authors	**Smith *et al.* (2017)**	**Moon, Martina, Peacher, Potter, *et al.* (2016)**	**Miller, Calder-Becker and Modave (2010)**	**Ludwig *et al.* (2006)**	**Adir *et al.* (2004)**	**Shupak *et al.* (2000)**	**Weiler-Ravell *et al.* (1995)**
Short term outcomes	N/A	N/A	N/A	All recovered at least 4 weeks prior to start of study	No hospitalisations. All recovered within 24 hours. Chest x-rays 12-18 hours later were all normal. Subsample of 37 trainees had restricted lung function for ≥1 week	Not reported	All stayed overnight in hospital and recovered within 24 hours
Recurrence	N/A	N/A	N/A	Not reported	22.9% of cases (*n*=16) had a recurrence during the study ≥3 months after first episode	31% (9 out of 29 episodes) were recurrences of observed episodes	25% of cases (2 trainees) had a recurrence later in training programme (not known when)
Long term health sequalae	N/A	N/A	N/A	No significant difference in cardio-pulmonary function between cases and controls at follow-up	Not reported	Not reported	Not reported
Quality of evidence							
Summary	Conference abstract so limited detail. Only included competitors that sought medical assistance. No information on demographics. Unclear if any cases were recurrences in same individual	Cases had a higher proportion of females and may have been physically fitter. Inconsistency between cases and controls in the way pre-exercise measurements were taken	Self-reported non-validated tool to detect cases. Very low response rate. Multivariate analyses did not control for age. Limited statistical power due to relatively small sample size. Unclear when health conditions were diagnosed and if medications taken	No SIPE symptoms observed. Small sample size. No further follow-ups	Unknown total number of swimmers and time trials. Unclear number of new cases versus recurrences. Spirometry only performed on subsample of 37	Non-validated self-reported tool to detect SIPE cases. Long duration between screening and field study measurements. Limited statistical power due to relatively small sample size. Study only lasted 2 months. No follow-up	Only one swimming trial. No clear case definition. Unclear when recurrences took place

MPAP = mean pulmonary artery pressure; PAWP = pulmonary artery wedge pressure; SEAL = Sea, Air and Land; SOB = shortness of breath

3.3.5 What is the effectiveness of interventions for preventing a recurrence of SIPE?

3.3.5.1 Description of studies

Only two relevant studies were found; a small clinical trial (Moon, Martina, Peacher, Potter, *et al.* 2016) and a single case report (Martina *et al.* 2017). Both studies examined the effect of the drug sildenafil on MAP, MPAP and PAWP. A description of the clinical trial (Moon, Martina, Peacher, Potter, *et al.* 2016) is included in section 3.3.3. Moon, Martina, Peacher, Potter, *et al.* (2016) compared outcomes before and after sildenafil in the SIPE participants. The second study was of a 46 year old elite female ultra-triathlete who had suffered ≥5 episodes of SIPE (Martina *et al.* 2017). The subject exercised for six minutes in 19°C water, before and after a 50mg oral dose of sildenafil. Measurements of MAP, MPAP and PAWP were taken at rest in dry conditions, and during immersed exercise both before and after sildenafil was administered. The woman also reported taking sildenafil before triathlons over the next five years and reported whether SIPE occurred.

3.3.5.2 Quality of studies

Both studies were small and did not include an untreated control group with a history of SIPE. The clinical trial did not report any clinical outcomes and the intervention did not take place in "real-world" conditions. As studies of effectiveness, then, they were of low quality. A strength of the case report was that the study participant reported clinical outcomes i.e. recurrences of SIPE over the following five years having taken sildenafil before triathlon events. See Appendix 3e for full results of the quality assessment

3.3.5.3 Findings

Moon, Martina, Peacher, Potter, *et al.* (2016) found that before taking sildenafil, both MPAP and PAWP were higher during exercise in cold water in SIPE subjects, compared to non-SIPE subjects. After taking sildenafil, MPAP and PAWP of SIPE subjects was reduced to a level similar to that of the non-SIPE subjects. In their case report, Martina *et al.*, 2017) showed a similar effect of sildenafil in that MPAP and PAWP were lower with sildenafil than without. Following the study, the subject took sildenafil before 20 triathlons over five years and experienced no recurrences of SIPE symptoms.

3.4 Discussion

3.4.1 Principal findings

I did not find conclusive evidence on the risk of developing SIPE for open water swimmers because the relevant studies differed greatly from each other in case definition, swimming environment, population characteristics and denominators (Weiler-Ravell *et al.*, 1995; Shupak *et al.*, 2000; Adir *et al.*, 2004; Miller, Calder-Becker and Modave, 2010; Smith *et al.*, 2017; Volk *et al.*, 2021; Lindqvist *et al.*, 2022; Sebreros *et al.*, 2023). However, SIPE appears to occur in approximately 1.4% of triathletes.

It seems likely that hypertension, taking fish oil supplements and long course triathlon distance are risk factors for developing SIPE, as are non-modifiable factors such as female sex, age >30 years, lower lung volumes and flows (Miller, Calder-Becker and Modave 2010; Shupak *et al.* 2000; Hårdstedt *et al.* 2021), and higher mean pulmonary artery pressures, pulmonary artery wedge pressures and tidal volumes during exercise in cold water (Moon, Martina, Peacher, Potter, *et al.* 2016). Testing positive for respiratory pathogens was proposed as a risk factor by Sebreros *et al.* (2023), however, the quality of the study is limited, so it is not possible to draw any conclusions. With the exception of female sex, the evidence for each of the above risk factors comes from only one study.

The evidence suggests that SIPE symptoms usually resolve quickly following an episode (Adir *et al.* 2004; Weiler-Ravell *et al.* 1995; Braman Eriksson, Annsberg and Hardstedt 2017; Melau *et al.* 2019), however this is not always the case, with one study reporting a symptom duration of over five days for 15–21% of cases (Kristiansson *et al.* 2023). I did not find any studies that reported deaths from SIPE. This may be due to difficulties differentiating between SIPE related deaths and those caused by drowning for other reasons (Papadodima *et al.* 2010). Four studies suggest that hospitalisation is not a common occurrence with between 0% and 7% of cases being admitted (Adir *et al.* 2004; Volk *et al.* 2021; Kristiansson *et al.* 2023; Sebreros *et al.* 2023). Whereas, all eight cases identified by Weiler-Ravell *et al.* (1995) and two of the three cases observed by Melau *et al.* (2019) were admitted to hospital overnight. Studies suggest that recurrences are common, although it is difficult to be sure of the size of the problem as the studies were in general not designed to quantify this (Adir *et al.* 2004; Shupak *et al.* 2000; Weiler-Ravell *et al.* 1995; Sebreros *et al.* 2023; Volk *et al.* 2021). One small study observed restrictive lung function defects that persisted for a week following SIPE (Adir *et al.* 2004). The single small study of the long term effects of SIPE on cardiopulmonary function only had a follow-up period of up to 14 weeks; it found no significant effects (Ludwig *et al.* 2006). I found one study of long term sequelae which reported a symptom duration of over 12 months for 4% of cases (Kristiansson *et al.* 2023). I found no conclusive evidence that sildenafil can prevent recurrences, although the studies' results suggest that it would be appropriate to investigate this drug further for this indication (Martina *et al.* 2017; Moon, Martina, Peacher, Potter, *et al.* 2016).

3.4.2 Strengths and weaknesses of the review

To my knowledge, this is the first systematic review to gather together all the available epidemiological evidence on SIPE occurrence, risk factors, prognosis and interventions to prevent recurrences. However, this research was limited by the small number of well-designed studies that have been published. My search strategy and inclusion criteria were broad to avoid omitting any potentially relevant publications. The decision to exclude studies of IPE in scuba divers and breath-hold divers as well as single case reports[4] and smaller case series/case control studies may have created a selection bias in favour of studies of young military trainees who are not representative of the general population of surface swimmers and triathletes. The exclusion of risk factor studies

[4] Case reports *were* included in the section addressing interventions to prevent SIPE recurrences due to the very limited amount of relevant literature

without an asymptomatic comparator group meant that very few risk factor studies met the inclusion criteria.

3.4.3 Strengths and weaknesses of the available evidence

Eight studies reported greatly varying figures for the incidence of SIPE. This variation may be explained by differences between the studies in swimming environment (e.g. fresh or sea water; water temperature; nature of competition – recreational or military, for example), study participant characteristics, study length and duration of follow up, case definition and ascertainment methods, time to follow-up and methods of analysis. None of the incidence studies fully censored participants who had developed SIPE. Incidence rates were reported in different ways depending on whether the denominator was the number of *swims* or *swimmers*. Only two of the eight incidence studies (Shupak *et al.*, 2000; Lindqvist *et al.*, 2022) collected data from all participants, rather than just those that were seen by a clinician, which resulted in incidence estimates that were much higher than the rest of the studies (apart from Weiler-Ravell *et al.* (1995) which was limited by a small sample size). This suggests that the incidence figures reported by Adir *et al.* (2004), Smith *et al.* (2017), Hårdstedt *et al.* (2021), Volk *et al.* (2021) and Sebreros *et al.* (2023) may be underestimates. The prevalence study of USA Triathlon members (Miller, Calder-Becker and Modave 2010) while fairly representative, was limited by the use of a self-completed non-validated questionnaire, narrow case definition and very low response rate.

One of the risk factor studies used a very large sample of competitive and recreational outdoor swimmers (Hårdstedt *et al.* 2021), however, the case definition was not consistent across the years of the event, and milder cases of SIPE may have been missed if the swimmer did not seek medical attention. Two of the risk factor studies were limited by the use of self-reported non-validated questionnaires to detect cases of SIPE and may have lacked statistical power due to the small number of SIPE cases included (Miller, Calder-Becker and Modave 2010; Shupak *et al.* 2000). This low statistical power meant that Miller, Calder-Becker and Modave (2010) were not able to demonstrate statistical significance for risk factors where ORs were >2, such as age 50–59, taking vitamin C, and pre-swim hydration of more than one litre. Miller, Calder-Becker and Modave, (2010) did not adjust for age in their multivariate analyses, and it is unclear if the health conditions reported by respondents were diagnosed before or after SIPE, or if individuals were taking medication. The remaining two risk factor studies were limited by the use of cases and controls that were substantially different and/or underwent different data collection methods. One was a small clinical trial where participants were not randomly selected and characteristics of cases and controls differed (Moon, Martina, Peacher, Potter, *et al.* 2016). The other was a study of US Navy SEAL trainees (Sebreros *et al.* 2023) where data for cases and controls were collected using different methods over different time periods. The lack of testing of controls for respiratory pathogens over the winter season is a serious limitation, meaning it is not possible to draw conclusions about risk factors from this study.

Most of the prognosis studies, apart from Kristiansson *et al.* (2023) were not designed as such and were heterogeneous, using different case definitions, outcomes and follow-up periods (Adir *et al.* 2004; Shupak *et al.* 2000; Weiler-Ravell *et al.* 1995; Ludwig *et al.* 2004; Braman Eriksson, Annsberg and Hardstedt 2017; Volk *et al.* 2021; Sebreros *et al.* 2023; Melau *et al.* 2019). The representativeness of participants is also unclear. In relation to early recovery, most of the findings correspond with those of a summary of published case reports in which symptoms resolved within 48 hours in 31 out of 38 reports (the symptoms persisting after 48 hours in seven non-resolved cases were not described) (Grünig et al., 2017). However, the more recent Kristiansson *et al.* (2023) study revealed that a substantial proportion (around a fifth) of cases had symptoms lasting beyond five days. Adir *et al.* (2004) suggested their findings of restrictive lung function deficit that persisted for a week following SIPE may indicate persistent pulmonary oedema and damage to capillaries. However, no symptoms and/or spirometric outcomes after this period were reported by the authors, so it is unclear how long the lung function deficit lasted or whether the participants had any clinical problems (Adir *et al.* 2004).

I found no studies reporting deaths of swimmers resulting from SIPE. Peacher *et al.* (2015), in a review of published case reports, identified six published reports of deaths from IPE, but only in scuba divers. Deaths from SIPE in surface swimmers may be underestimated, especially those occurring during unsupervised training sessions in open water, which may be attributed simply to drowning. There is no separate International Classification for Diseases (ICD) code to identify deaths caused by SIPE. Harris *et al.* (2004) studied 2,971 USA Triathlon events from January 2006 to September 2008 and discovered 13 swim related deaths that occurred during 13 triathlons; drowning was declared the cause of death for each one. In a study of 135 deaths and cardiac arrests in US triathlon participants between 1985 and 2016, Harris *et al.* (2017) discovered 85 deaths that occurred during the swim phase. This accounted for 70% of all triathlon deaths, however, the individual causes of death were not reported for these particular cases.

Information on the long term effects of SIPE is lacking; only two studies met the inclusion criteria. At a 30 month follow up, one study found a small number of cases reported symptoms lasting beyond 12 months (Kristiansson *et al.* 2023). The other study was very small and only studied patients up to 14 weeks after recovery from SIPE and did not ask the patients about their symptoms, focusing only on measures of cardiopulmonary function (Ludwig *et al.* 2004). The findings of a study of scuba divers showed a similar result; six months after admission for IPE, respiratory function, cardiac echography and exercise tolerance tests were all normal (Coulange *et al.* 2010). However, this study also did not report symptoms, which may have been present despite undetectable changes in investigations.

The studies suggest that recurrence of SIPE is common, although the different study designs used make it difficult to assess the accuracy and precision of the findings.

Two intervention studies suggested that sildenafil may be useful as a treatment to help reduce the risk of recurrence of SIPE in susceptible individuals, but the evidence is inconclusive. Neither was controlled by including an untreated control group with a history of SIPE, nor reported any clinical outcomes.

3.4.4 Risk factor mechanisms

There has been much discussion on the mechanisms that lead to an increased risk of SIPE. The association between hypertension and IPE has been widely considered (Peacher *et al.* 2015; Gempp, Demaistre and Louge 2014; Wilmshurst *et al.* 1989). Hypertension can lead to diastolic dysfunction which is thought to increase the pressure in the pulmonary capillaries resulting in fluid leaking into the alveoli (Miller 2011). Wilmshurst *et al.* (1989) found that blood pressure in a group of 11 SIPE susceptible divers became significantly higher than the control group following exposure to cold and/or raised partial pressure of oxygen. Peacher *et al.* (2015) carried out a literature review of 292 cases of pulmonary oedema in swimmers and divers, as well as a case series study (*n*=36). They found that 16% of the recreational swimmers and divers were reported to have hypertension, as were 17% of cases in their case series. Gempp, Demaistre and Louge (2014) found that 23% of the 73 scuba divers treated for IPE at a French hyperbaric facility, suffered from hypertension. However, these hypertension prevalence figures for IPE cases reported by Peacher *et al.* (2015) and Gempp, Demaistre and Louge (2014) are lower than the 2019 World Health Organization region age standardised prevalence estimates for adults aged 30–79 (Europe: 36.9%, Americas: 35.4%, Eastern Mediterranean: 37.8%) (World Health Organization 2024), so do not show a clear link between hypertension and IPE.

The connection between SIPE and fish oil consumption is believed to be caused by its anti-platelet and vasodilatory effect which can make it easier for fluid to pass into the pulmonary capillaries (Miller, Calder-Becker and Modave 2010). The use of the anti-platelet medication aspirin in breath-hold divers has also been linked to three cases of SIPE in a small case series (Boussuges *et al.* 1999).

Miller, Calder-Becker and Modave (2010) suggested the relationship between long course distance and SIPE may be related to wetsuit use, since the authors were unable to separate the effects of these two factors. Older age has been proposed as a possible risk factor for IPE in scuba divers (Hampson and Dunford 1997; Cochard *et al.* 2005) and for SIPE among open water swimmers (Hårdstedt *et al.* 2021). Miller, Calder-Becker and Modave (2010) reported a greater prevalence of SIPE among triathletes aged 40 and over, although they did not find a significant association. The increasing prevalence of hypertension and other age related changes to cardiovascular function that lead to increased pulmonary artery pressures, have been put forward by some as the mechanism responsible for the association between SIPE and age (Hårdstedt *et al.* 2021; Miller, Calder-Becker and Modave 2010). Age-dependent increases in pulmonary artery pressures during exercise have also been reported in a systematic review by Kovacs *et al.* (2009), who found significantly higher pressures in participants aged ≥50 compared to those age <50.

Hårdstedt *et al.* (2021) reported female sex as a risk factor for SIPE. The relationship between IPE and female sex was previously discussed by Coulange *et al.* (2010) who reported a statistically higher incidence of pulmonary oedema in female scuba divers. Guenette *et al.* (2007) tested the response to exercise of endurance trained athletes and found there were disadvantages in pulmonary response to exercise of females that was probably due to lung size. Hopkins *et al.* (1998) suggested smaller lung size might be the mechanism by which females are at a higher risk of pulmonary oedema. The findings of Shupak *et al.* (2000) that affected military trainees had significantly smaller initial lung volumes and flows suggests that even in males, smaller lung volumes may lead to a greater risk of SIPE. In a study of a small number of SIPE and HAPE (high altitude pulmonary oedema) subjects and controls, Carter *et al.* (2014) found no significant difference in lung volumes, however, the SIPE/HAPE subjects *did* have a lower lung density and mass, and fewer pulmonary lymphatics. The authors hypothesized that a limited pulmonary lymphatic system was less able to reabsorb excess fluid that leaked into the interstitial and alveolar space, leading to a greater risk of pulmonary oedema.

3.4.5 Recommendations for future research

Future studies of the frequency of SIPE should focus on those with milder symptoms in order to reflect the true burden of this condition. Larger studies that can replicate the findings on age, sex, hypertension, fish oil consumption, long course distance, lower lung volumes and flows, higher pulmonary artery pressures and pulmonary artery wedge pressures and lower tidal volumes during exercise in cold water, as risk factors for SIPE, are needed to improve our understanding of SIPE. Future research should explore other proposed risk factors such as wetsuit use, wetsuit fit, over hydration, water temperature, swimming position, exertion, presence of respiratory pathogens or specific gene variants, failure to warm up and variations in physiological stress response. More studies are needed that examine the effects of SIPE on the cardiorespiratory system over the months and years after the initial or repeated episode, including studies of symptoms as well as cardiovascular and respiratory function tests. Sildenafil has showed promise as a potential prophylactic against SIPE; the drug now needs to undergo randomised controlled trials to determine its efficacy.

3.5 Conclusion

The evidence on the occurrence of SIPE suggests that it is a significant public health issue for recreational endurance open water swimmers, clinicians and event organisers, which is particularly important given the popularity of this sport in the UK and other countries. It is likely that current estimates are underestimates of the true burden of this condition. It appears that recurrence rates are high, so it is important to advise SIPE patients of this and recommend close supervision by others who can help them get out of the water if affected.

Chapter 4: Questionnaire development, testing and validation

4.1 Introduction

The purpose of this chapter is to describe the development, testing and validation of two questionnaires designed to identify outdoor swimmers who have experienced SIPE, and collect information on risk factors and outcomes. The reason for doing this was because the systematic review found that the evidence base for SIPE occurrence, risk factors and outcomes was very limited and there were no existing validated tools designed to collect this information (see chapter 3). It was of particular importance to establish whether any observed statistical associations represented a causal relationship between the exposure and SIPE.

I decided to carry out an online survey to provide much needed additional evidence on SIPE occurrence – either prevalence of having had SIPE or incidence of SIPE, and to study risk factors and outcomes. I searched for existing validated tools that could be used to collect this information. Two studies included in my systematic review involved the use of a questionnaire to detect cases of SIPE and collect information on risk factors and/or outcomes. Miller, Calder-Becker and Modave (2010) developed an online questionnaire to collect data from US triathletes on swim related breathing problems, demographics, family medical history, swimming habits, and conditions at the time of the initial episode, which was pilot tested with three small groups of triathletes. Shupak *et al.* (2000) designed a questionnaire to collect information from Israeli military trainees on SOB, cough, haemoptysis and exertion levels after they took part in swimming time trials. The authors did not specify if any testing or validation of the questionnaire took place.

In the absence of a fully tested and validated tool, I needed to develop, test and validate a new SIPE questionnaire to detect cases of SIPE and collect information on risk factors and outcomes. To do this, it was necessary to have a definition of 'caseness'. Case definitions are a set of criteria which determine whether a person is affected by a specific condition in epidemiological studies. In clinical settings, diagnostic criteria are used to diagnose an individual patient. These are based on clinical symptoms and signs, and sometimes include laboratory test result or imaging findings. Epidemiological case definitions are used to identify cases of a disease at a population level for surveillance or research purposes.

Ideally, a case definition will include all cases i.e. high sensitivity, but will not include people who do not have the condition i.e. high specificity. Standardised case definitions allow a condition to be identified and reported in a consistent manner. For example the World Health Organisation (WHO) has developed standard case definitions for diseases such as COVID-19, human influenza, polio, SARS and smallpox, based on a limited set of symptoms, to enable the consistent reporting of cases (WHO 2005; WHO 2022). Standard case definitions have also been developed for non-communicable diseases, such as cardiovascular disease, childhood asthma, COPD, and inflammatory bowel diseases (Thomas *et al.* 2023; Geller *et al.* 2021; Feinstein *et al.* 2020; Rezaie *et al.* 2012).

However, there are many conditions for which no standardised case definition or diagnostic criteria exists. For example, when health conditions are first recognised they do not always have standard diagnostic criteria until a consensus is built on symptoms, signs, and laboratory or imaging findings. For example, diagnostic criteria for HIV, Alzheimer’s Disease and diabetes mellitus were developed over time as our understanding of the conditions evolved (Alexander 2016; Ahmed, Ahmed and Imtiaz 2021; Decode Study Group 1998).

SIPE does not yet have a standardised case definition, although a clinical algorithm for diagnosis of SIPE was recently proposed by Hårdstedt *et al.* (2020) based on peripheral oxygen saturation levels, the presence of crackles, and lung ultrasound scans in some cases. SIPE is characterised by distinct short-lived episodes, which means it is not always possible for symptoms to be observed by a clinician; swimmers often do not seek medical help, or if they do, symptoms may have disappeared by the time they are seen.

Radiography can be used to diagnose SIPE, but this usually requires a hospital attendance unless it can be performed in the field as is sometimes the case with lung ultrasound. However, hospital attendances are fairly uncommon among SIPE cases according to the four larger prognosis studies included in my systematic review (Adir *et al.* 2004; Volk *et al.* 2021; Kristiansson *et al.* 2023; Sebreros *et al.* 2023). Imaging may not be a very reliable method of identifying SIPE either, given the findings of a review article by Grünig *et al.* (2017) that 10 out of 34 SIPE cases who underwent radiological examination had normal findings.

Given there is no standard method for identifying SIPE, either in clinical practice or in epidemiological studies, it was necessary for me to develop my own case definition to use in my questionnaires. I planned to use these questionnaires to conduct an online survey of competitors of outdoor swimming events. The questionnaires were designed to collect data to answer the following five research questions:

1. What is the prevalence of having ever experienced SIPE in competitors of open water swimming events in 2019?
2. What is the incidence of SIPE in competitors of open water swimming events in 2019?
3. What are the risk factors associated with SIPE?
4. What are the short-term outcomes of SIPE?
5. How common are SIPE recurrences?

By prevalence, I mean the proportion of swimmers that had ever experienced SIPE. This is because the condition is characterised by short-lived episodes of symptoms that then appear to resolve, therefore prevalence of episodes themselves is necessarily low. Incidence refers to the number of swimmers that experienced SIPE during or immediately after selected open water swimming events, as a proportion of all event competitors. Risk factors include characteristics of swimmers or exposures that were associated with an episode of SIPE. I categorised risk factors into modifiable, non-modifiable and comorbidities.

Short-term outcomes refer to what happened within a few hours after the onset of SIPE. This includes whether the swimmer carried on swimming after the episode began, how far they swam, and details of any medical attention received. Information about the number of previous SIPE episodes was collected to provide information on the frequency of recurrent SIPE episodes.

Once the questionnaires had been developed, they underwent testing and validation to ensure the instruments were reliable, accurate and effective for gathering the intended data. My questionnaire testing and validation process aimed to address the following research questions:

- Are the questions understandable and acceptable?
- Are the questions valid?
- Are the questions reliable?

Are the questions understandable and acceptable?

It is important to ensure that participants understand the questions, interpret them in the way that was intended, and are given appropriate options to provide an answer. I also wanted to ensure that the questions did not make anyone feel uncomfortable in any way. This was particularly important as some questions requested information on sensitive issues such as weight, health conditions and medication.

Are the questions valid?

Validity is defined as "*the degree to which a test measures what it purports to measure*" (Garrett 1937). In this study I was concerned with the degree to which the questionnaire items measured what they intended to measure. I was mainly interested in content validity and criterion validity. Content validity refers to the whether or not the items in the questionnaire fully take into account the full range of domains of the construct i.e. does the content measure what it is supposed to and does it cover all appropriate areas of the given topic? For example, my questionnaire needed to collect all the information required for the constructs of interest listed in section 4.2.2.1. Criterion validity is concerned with how the measure correlates with the "gold standard" i.e. are the questionnaire items able to identify or rule out SIPE based on the responses from a person who has received a clinical diagnosis of SIPE. In this case it examined if the group that had been diagnosed with SIPE gave different responses to the questionnaire compared to those who had not, and those who had other cardiorespiratory conditions that could cause breathing difficulties.

Are the questions reliable?

Reliability refers to the degree to which the responses obtained by the questionnaire can be replicated. In this case I was interested in whether respondents gave the same answers to the questionnaire the second time, after a 2–4 week time lapse.

4.2 Methods

This section describes the process I went through to design, test and validate the survey instruments.

4.2.1 Target population

The questionnaires were initially designed to be completed by adult competitors of open water swimming races at large triathlon events in the UK.

4.2.2 Questionnaire development

I developed questionnaire items by setting out the constructs of interest i.e. the underlying concepts or themes for which I wanted to collect data. I decided on the format of the questionnaires, as well as the type and format of the questions. I then drafted the questionnaire items and response options.

4.2.2.1 Constructs of interest

I began developing the questionnaires by setting out the constructs of interest to be assessed.

SIPE symptoms

This was one of the most important parts of the questionnaires as it enabled me to identify cases of SIPE. In my systematic review I found case definitions for SIPE used by other researchers varied considerably. Some studies used fairly narrow definitions such as Miller, Calder-Becker and Modave (2010) who limited their case definition to *"cough productive of pink frothy or blood-tinged secretions"*, whereas others required a clinical examination to identify SIPE through a combination of symptoms and signs (Kristiansson *et al.* 2023; Sebreros *et al.* 2023; Lindqvist *et al.* 2022; Hårdstedt *et al.* 2021; Volk *et al.* 2021; Melau *et al.* 2019; Braman Eriksson, Annsberg and Hardstedt 2017; Smith *et al.* 2017; Ludwig *et al.* 2006; Adir *et al.* 2004; Weiler-Ravell *et al.* 1995) (see Tables 8 and 9). Shupak *et al.* (2000) used a much broader case definition; SOB and coughing in the absence of water aspiration, and did not require examination by a clinician to detect SIPE. This enabled them to identify milder cases of SIPE in addition to those who sought medical attention, which led to a higher rate of incidence being reported. Two recent reviews which covered published case reports and case series (Grünig *et al.* 2017; Hohmann, Glatt and Tetsworth 2018) found that the three most common SIPE symptoms reported were SOB, cough, and coughing up bloody/frothy sputum.

In this study I aimed to collect information on as many as symptoms as possible, so I could explore the effect of different SIPE case definitions.

Attribution of symptoms

In order to improve specificity and avoid misclassifying any other cause of SOB as SIPE, I aimed to ask the respondent what they attributed their SOB to i.e. asthma, chronic bronchitis, COPD, nasal allergies, pneumonia, emphysema, cold shock response, panic attack, smoking, and whether this had been confirmed by a health professional. However, it is possible that people may attribute what was actually SIPE to other things.

Table 8: SIPE case definitions used by studies included in systematic review

Authors	Case ascertainment method	Case definition
Kristiansson *et al.* (2023)	Clinical presentation at the event	SOB and/or cough and (chest crackles and/or oxygen saturation ≤95%) or (pulmonary oedema on lung ultrasound scan, if performed)
Sebreros *et al.* (2023)	Those who sought medical help	SOB and blood in sputum during or shortly after swim, and chest crackles or oxygen saturation <95%, and chest x-ray showed pulmonary oedema, and improvement of symptoms and signs within 48 hours
Lindqvist *et al.* (2022)	All swimmers underwent an LUS and rated their SOB upon leaving the water	SOB and pulmonary oedema on lung ultrasound scan
Hårdstedt *et al.* (2021)	Those who sought medical care at the event	2016: SOB and/or cough, chest crackles and low oxygen saturation; 2017: SOB and/or cough, and chest crackles or oxygen saturation ≤95%; 2018 and 2019: SOB and/or cough, and pulmonary oedema on lung ultrasound scan
Volk *et al.* (2021)	Retrospective diagnosis by 2 chest physicians using clinical data and chest x-rays of swimmers who sought medical attention	Respiratory symptoms, and frothy or bloody sputum, and (pulmonary oedema on chest x-ray or symptoms that resolved within 24 hours)
Melau *et al.* (2019)	Clinical presentation at the event	SOB, chest tightness and pink sputum
Braman Eriksson, Annsberg and Hardstedt (2017)	Clinical examination of competitors presenting to medical team	No standard definition. Examining physicians identified cases without a formal case definition
Smith *et al.* (2017)	Medical records of competitors presenting to medical team	SOB, cough and/or frothy sputum, in absence of water aspiration, with evidence of pulmonary oedema on physical examination
Moon *et al.* (2016)	Not reported	No case definition provided
Miller, Calder-Becker and Modave (2010)	Questionnaire to all USA Triathlon members for incidence study plus 11 additional cases from slowtwitch.com for risk factor study	Cough productive of pink frothy or blood-tinged secretions
Ludwig *et al.* (2006)	Previous clinical diagnosis of a single episode of SIPE	SOB or blood in sputum during or immediately after swimming, in the absence of water aspiration, airway blockage by vocal cord spasm, or respiratory infections, and oxygen saturation <92% or alveolar-arterial oxygen gradient of >30mm Hg, and pulmonary oedema on x-ray that resolved within 48 hours
Adir *et al.* (2004)	Interview and clinical examination of swimmers presenting to medical team	Severe SOB and coughing during or after swimming in the absence of water aspiration, and evidence of pulmonary oedema on physical examination
Shupak *et al.* (2000)	All trainees were examined and completed post-swim questionnaire	SOB and cough in the absence of water aspiration
Weiler-Ravell *et al.* (1995)	Clinical examination of trainees presenting to medical team	SOB and blood in sputum

SOB = shortness of breath

Table 9: Clinical characteristics included in SIPE case definitions used by studies included in systematic review

Authors	SOB	Cough	Tight chest	Chest crackles	Bloody/ frothy sputum	Unspecified respiratory symptoms	Absence of water aspiration	Absence of airway blockage by other cause[1]	Low oxygen saturation	Alveolar-arterial oxygen gradient of >30mm Hg	Pulmonary oedema on lung ultrasound scan	Pulmonary oedema on chest x-ray	Pulmonary oedema on physical examination	Symptoms resolve within 24 hours	Symptoms resolve within 48 hours
Kristiansson *et al.* (2023)	✓	✓		✓					✓		✓				
Sebreros *et al.* (2023)	✓			✓	✓				✓			✓			✓
Lindqvist *et al.* (2022)	✓										✓				
Hårdstedt *et al.* (2021)[2]	✓	✓		✓					✓						
Hårdstedt *et al.* (2021)[3]	✓	✓									✓				
Volk *et al.* (2021)					✓	✓						✓		✓	
Melau *et al.* (2019)	✓		✓		✓										
Braman Eriksson, Annsberg & Hardstedt (2017)	No standard definition. Examining physicians identified cases without a formal case definition.														
Smith *et al.* (2017)	✓	✓			✓		✓						✓		
Moon *et al.* (2016)	No case definition provided.														
Miller, Calder-Becker & Modave (2010)		✓			✓										
Ludwig *et al.* (2006)	✓				✓		✓	✓	✓	✓		✓			✓
Adir *et al.* (2004)	✓	✓					✓						✓		
Shupak *et al.* (2000)	✓	✓					✓								
Weiler-Ravell *et al.* (1995)	✓				✓										

SOB = shortness of breath; [1] Vocal cord spasm or respiratory infections; [2] Case definition used in 2016 and 2017 studies; [3] Case definition used in 2018 and 2019

Non-modifiable risk factors

I listed as many as possible of the suggested or hypothesized non-modifiable risk factors for SIPE. These included female sex, advancing age, lower lung volumes and flows, and health conditions.

Female sex

Female sex was reported as a risk factor among triathletes and competitors of an outdoor swimming race by two studies (Miller, Calder-Becker and Modave 2010; Hårdstedt *et al.* 2021). Other studies have reported a disproportionate number of females experiencing pulmonary oedema during outdoor swimming (Braman Eriksson, Annsberg and Hardstedt 2017) and diving (Coulange *et al.* 2010; Edmonds, Lippman and Bove 2019; Henckes *et al.* 2019). The mechanism for this is still unclear, however, there are suggestions it may be related to female differences in lung anatomy and cardiopulmonary response to exercise and stress, endothelial function (the membrane that lines the inside of vascular system) and higher risk of some cardiovascular diseases such as pulmonary hypertension, stress-induced cardiomyopathy and age-dependent diastolic heart dysfunction (Beale *et al.*, 2018 as cited by Hårdstedt *et al.*, 2020).

Older age

Hårdstedt *et al.* (2021) found that age>30 was associated with SIPE, with ORs increasing with age. Advancing age has also been reported as a possible risk factor for IPE in scuba divers (Hampson and Dunford 1997; Cochard *et al.* 2005). Miller, Calder-Becker and Modave (2010) observed that SIPE was more prevalent in those aged over 40, however, this association was not statistically significant due to the small number of cases and therefore, likely low statistical power. Taylor *et al.* (2014) described some of the changes that take place in the lungs during healthy ageing which can lead to an increase in pulmonary vascular pressures during rest or exercise. They also suggested ageing can affect the lymphatic system making it less effective at clearing excess fluid from the interstitial space and alveoli (Taylor *et al.* 2014).

Lower lung volumes and flows

A number of studies have hypothesized that lower lung volumes (Shupak *et al.* 2000; Martina *et al.* 2017; Moon, Martina, Peacher, Potter, *et al.* 2016), lower lung density and mass, and fewer pulmonary lymphatics (Carter *et al.* 2014) increase the risk of pulmonary oedema. Small lung size has also been suggested as contributing factor in the development of interstitial oedema during heavy exercise in athletes (Hopkins *et al.* 1998).

Health conditions

In a case-series of 36 individuals who had experienced SIPE, Peacher *et al.* (2015) reported that 72% had at least one comorbidity such as hypertension, cardiac issues, asthma or diabetes, or were overweight. The same authors reviewed cases of SIPE reported in published literature and found a prevalence of concurrent medical conditions of 44.9% in recreational swimmers and divers. Miller, Calder-Becker and Modave (2010) reported a strong association between hypertension and SIPE among US triathletes. In a study of 165 SIPE cases, Hårdstedt *et al.* (2021) reported asthma as the most frequently reported comorbidity (*n*=30), followed by hypertension (*n*=24) and heart disease (*n*=6).

Modifiable risk factors

I made a list of known or suspected modifiable risk factors for SIPE. These included swimming distance, wetsuit use, level of hydration, water temperature, degree of exertion, variations in physiological stress response, BMI, smoking, alcohol consumption, use of medications or dietary supplements, and degree of cold water habituation.

Swimming distance

Miller, Calder-Becker and Modave (2010) found that a course distance of ≥1.9km was a significant risk factor for SIPE among US triathletes, although they were unable to separate this effect from wetsuit use due to the limited statistical power of the study, and high levels of wetsuit use among long distance swimmers. However, other studies have reported cases of SIPE during varying swimming distances including 400–1,500m in triathletes (Smith *et al.* 2017), 1–3km in swimming race competitors (Hårdstedt *et al.* 2021) and 2.4–3.6km in Israeli military trainees age 18–19 (Weiler-Ravell *et al.* 1995; Shupak *et al.* 2000; Adir *et al.* 2004).

Wetsuit use

In their univariate regression analyses, Miller, Calder-Becker and Modave (2010) identified wetsuit use as a risk factor for SIPE, however, the OR was no longer significant when female sex was controlled for. This indicated the relationship between wetsuit use and SIPE in their study may be explained by higher wetsuit use among women.

Level of hydration

A study of eight male military trainees who developed SIPE reported that all had consumed five litres of water in the two hours prior to swimming, although two recurrences did not involve overhydration (Weiler-Ravell *et al.* 1995). The authors hypothesized that fluid overload increases circulating plasma volume, exacerbating immersion effects of central blood pooling and greater cardiac preload, leading to increased pulmonary artery pressures.

Water temperature

Exposure to cold water causes peripheral vasoconstriction, which increases venous return, cardiac output and central blood volume, leading to higher pulmonary vascular pressures (Wester *et al.* 2009). There are a number of studies that have reported exposure to cold water as a risk factor for IPE in scuba divers and swimmers (Wilmshurst *et al.* 1989; Pons *et al.* 1995; Hampson and Dunford 1997; Coulange *et al.* 2010; Biswas, Shibu and James 2004).

Exertion

High levels of exertion were described as a factor in many reported cases of SIPE (Weiler-Ravell *et al.* 1995; Shupak *et al.* 2000; Mahon *et al.* 2002). Exercise is known to increase cardiac output in order to meet the body's higher demand for oxygen, leading to increased pulmonary capillary pressures. In some cases these increases in pressure when exercising on dry land can become high enough to cause exercise-induced pulmonary oedema, however, this is thought to be a fairly rare occurrence (Bates, Farrell and Eldridge 2011).

Medications

Many commonly prescribed medications can affect blood pressure, vascular tone, heart rate, antiplatelet activity, and sympathetic nerve activity. These include antihypertensive medications, asthma treatments, drugs for mood disorders, female sex hormones, and antiplatelet medicines. Drugs with antiplatelet activity, such aspirin and clopidogrel, reduce the ability of platelets in the blood to stick together and form clots that can lead to a heart attack or stroke. Aspirin, however, has been linked to a small number of cases of non-cardiogenic pulmonary oedema in breath-hold divers (Boussuges *et al.* 1999). The authors suggested the antiplatelet effect of aspirin may have exacerbated the bleeding.

Dietary supplements

Some dietary supplements are reported to have antiplatelet effects. These include omega-3 (including fish oil and vegetarian versions) (Gao *et al.* 2013), turmeric (Tabeshpour, Hashemzaei and Sahebkar 2018) and vitamin C (Pignatelli *et al.* 2005). In their study of US triathletes, Miller, Calder-Becker and Modave, 2010) reported a significant association between the consumption of fish oil supplements and SIPE, and suggested the antiplatelet activity of fish oil may have played a part in the pulmonary capillary leak.

Other effects of dietary supplements have been reported, such as cardiac symptoms, allergic reactions and swallowing problems. Geller *et al.* (2015) studied data from 63 US emergency departments over a 10 year period and identified over 3,600 attendances attributable to dietary supplement use. In an analysis of attendances for cardiovascular problems such as palpitations, chest pain or tachycardia (heart rate >100 beats per minute), the authors found that 72% were likely due to weight loss and energy supplement use.

Harmful drug interactions between dietary supplements and prescribed medications could potentially increase the risk of SIPE due to mechanisms that affect cardiovascular function. In their overview of systematic reviews into herb-drug interactions, Posadzki, Watson and Ernst (2013) reported adverse effects associated with the following herbal medicines; ginkgo, ginseng, green tea, kava, mistletoe, saw palmetto, and St John's wort. Anticoagulant drugs and antiplatelet agents were the most common interacting drugs.

Variations in physiological stress response

Physiological stress caused by cold temperatures, exercise, immersion, or psychological factors such as panic or nervousness, activates the sympathetic nervous system, releasing stress hormones like adrenaline and cortisol. This can cause the "fight or flight" response, which leads to vasoconstriction in certain areas and the redirection of blood flow to vital organs. Heart rate increases leading to greater cardiac output and increased pulmonary artery pressures. This physiological response can also release certain cytokines and growth factors that affect the endothelium and can increase capillary permeability. Physiological stress reactivity varies between individuals depending on a number of factors, including genetic variation (Wüst *et al.* 2004), early life adversity (Bunea, Szentágotai-Tătar and Miu 2017), being overweight or obese (Jones *et al.* 2012), and physical activity (Mücke *et al.* 2018), as well as emotional exhaustion and time pressure (Schmid, Thomas and Rentzsch 2024).

Lower BMI

Some studies suggest that overweight and obese individuals experience less of an increase in blood pressure during the cold pressor test[5] compared to those of a normal weight (Garg *et al.* 2013; Grewal *et al.* 2015; Grewal and Gupta 2020). I hypothesized that this could mean that people with a

[5] The cold pressor test is a cardiovascular test that involves immersing a hand or foot in cold water to measure changes in heart rate and blood pressure.

lower BMI may experience an increased vasoconstriction response during cold exposure. However, a recent study by Eglin *et al.* (2021) suggests cold reception and stimulation occurs from cold receptors that are 0.18 mm from the surface of the skin and above any subcutaneous fat layer, which means that BMI is unlikely to affect the vasoconstriction response.

Smoking

Long-term effects of cigarette smoking include narrowing and stiffening of blood vessels in the lungs, which could lead to increased pulmonary artery pressures (Santos *et al.* 2002).

Alcohol consumption

High levels of alcohol consumption over time can also result in the narrowing and stiffening of blood vessels (Hwang *et al.* 2022).

Cold water habituation

Studies have shown that cold water habituation, or immersing oneself in cold water repeatedly over a number of days can lead to a reduction in the body's physiological response to cold (Tipton *et al.* 1998). I hypothesized that this could lead to blunted vascular reactivity to cold and therefore a reduction in cutaneous vasoconstriction, less venous return, lower cardiac output and a smaller increase in pulmonary artery pressures. However, a recent study found that previous exposure to cold temperature was associated with a lower skin blood flow (Eglin *et al.* 2021).

Type of swimmer

I hypothesized that people who take part in multisport events that involve running or cycling as well as outdoor swimming may be more likely to experience SIPE than those who only do outdoor swimming, due to differences in characteristics and behaviours. I theorised that those who take part in multisport events may have a lower BMI and be more likely to wear a wetsuit and swim at higher exertion levels, compared to those that don't.

Outcomes

My systematic review found a lack of evidence about what happened to people in the few hours after a SIPE attack. I listed the types of information that would be useful for this construct:

- Distance swum
- Whether planned swim distance was completed
- Whether the individual was seen by a health professional and if so, where the patient was seen i.e. on-site, ambulance, hospital A&E
- Type of medical care received
- Whether the patient was admitted to hospital overnight
- Length of hospital admission

Demographics

Information on the age and sex of respondents was necessary to determine the representativeness of the sample compared to the overall population of triathletes and outdoor swimmers. In addition, I needed to control for these factors in adjusted regression analyses, because they can act as confounders due to their strong influence on health outcomes.

4.2.2.2 Questionnaire format

I developed two questionnaires aimed at competitors of open water swimming events; a pre-race and post-race questionnaire. The aim of the pre-race questionnaire was to identify people who had experienced a previous episode of SIPE and to collect data on comorbidities, medications/dietary supplements taken, swimming habits, health behaviours, anthropometrics and demographics. The post-race survey was designed to identify people who had experienced an episode of SIPE at the selected event, and to collect data on water temperature, attribution of SOB symptoms, outcomes and swimming behaviours at the event e.g. pre-race drinks, wetsuit use, swimming distance, exertion levels, and anxiety during swimming.

I chose to set up the questionnaires as online Qualtrics surveys since they are a very cost effective and time efficient way of collecting large amounts of data compared to paper surveys, and enable survey links to be shared widely. Respondents can complete the forms in their own time and data is immediately captured and stored in electronic format ready for analysis, without the need for any data inputting.

4.2.2.3 Item format

I included mostly closed rather than open questions to allow for more straightforward analyses. I limited the number of response options to make the questions easier to answer and enhance decision making. The disadvantages of this type of question are that responses will be very much dependent on the options provided and respondents have no way of clarifying their responses (Tsang, Royse and Terkawi 2017). For this reason, I included a small number of open-ended questions where relevant, to allow respondents to provide some contextual data.

4.2.2.4 Item development

For each of the constructs mentioned in the introduction section, I drafted a number of questions. I was given access to the questionnaire used by Miller, Calder-Becker and Modave (2010), so was therefore able to use and adapt some of the items into my survey tool. I also searched the web and literature for any relevant items from existing questionnaires e.g. the UK Data Service question and variable bank (UK Data Service 2024).

In addition to the two questionnaires above, I drafted a feedback questionnaire to gather comments and opinions on the pre- and post-race questionnaires from questionnaire testing participants (see Appendix 10).

In developing the item wording, I followed guidelines which I adapted from Leung (2001) and Artino *et al.* (2014):

1. Maximise response
    - Use short and simple sentences
    - Ask for only one piece of information at a time
    - Ensure respondents have the necessary knowledge
    - Avoid unnecessary details, as people are usually less inclined to complete long questionnaires
    - Label each response option and use additional space to visually separate non-substantive response options e.g. don't know, not applicable, no opinion, from the substantive options
    - Arrange the questions so they go from general to particular, easy to difficult, and factual to abstract
2. Ensure unambiguous meaning
    - Ask precise questions
    - Avoid words such as commonly, usually, some, and hardly ever as they are ambiguous and can be misleading
    - Avoid using statements instead of questions
    - Avoid negatives if possible
3. Avoid causing distress i.e. avoid asking direct questions on sensitive issues
4. Minimise bias
    - Avoid questions where participants may answer yes to please you
    - Avoid using agreement response options as respondents may be prone to acquiescence (i.e. the tendency to agree with any assertion made in an item, regardless of its content). Instead, use construct-specific response options.
    - Avoid using too few or too many response options. Use five or more response options to achieve reliability. In most cases, using more than seven to nine options is unlikely to be meaningful to most respondents and will not achieve stable participant responses.

- Consider adding some contradictory questions to detect the respondents' consistency

4.2.1.5 Questionnaire length

A meta study of questionnaire length and breakoffs (when respondents do not finish completing the questionnaire) in web surveys found the recommended length of questionnaires varied considerably, but there was an association between questionnaire breakoffs and questionnaire length, e.g. doubling questionnaire length increased the breakoff rate by roughly half (Vehovar and Cehovin 2014). The authors reported that questionnaire duration >20 minutes led to data quality deterioration i.e. a high level of breakoffs. I therefore intended to keep the questionnaires to an expected completion time of <10–15 minutes.

4.2.3 Questionnaire testing and validation

I carried out preliminary pilot tests of the questionnaires, followed by online tests with a group of outdoor swimmers, and a small number of cognitive interviews. This was followed by an expert review and field testing with competitors of an outdoor swimming event. The process was iterative, with questionnaire items refined and improved at every stage. Ethical approval was received from University of Kent SRC ethics committee (SRCEA id 223) (see Appendix 4a). The following sections describe each part of the questionnaire testing and validation process in more detail.

4.2.3.1 Preliminary pilot tests

After I drafted the initial pool of questionnaire items, I carried out some preliminary tests with colleagues who were outdoor swimmers. This process was designed to highlight any issues regarding understandability and clarity of the wording and response options, which could then be addressed in a revised version of the questionnaires.

4.2.3.2 Online tests

I asked a group of outdoor swimmers to complete my draft online questionnaires (see Appendix 8 and Appendix 9, as well as a short feedback questionnaire (see Appendix 10). The aim of the online testing was to determine whether the questionnaire items met the following criteria:

- Understandable i.e. did the participants interpret the questions in the way that was intended?
- Acceptable i.e. did the questions make anyone feel uncomfortable in any way?
- Provided appropriate response options i.e. were respondents able to easily select an appropriate response?
- Collected the data that was required

Questionnaire testing participants comprised three groups; those who had previously been diagnosed as having experienced an episode of SIPE, those who had never been diagnosed with SIPE and had no cardiorespiratory conditions, and those who had never been diagnosed with SIPE and suffered from asthma or other cardiorespiratory conditions.

Participants were emailed a link to the pre-race and post-race questionnaires, and feedback questionnaire, and invited to complete them. The feedback questionnaire used open questions to ask respondents how they found the understandability of the pre and post-race questionnaires, what, if anything made them feel uncomfortable, any difficulties experienced in answering questions, and how they felt about the length of the questionnaires. There was also an opportunity to provide further comments.

I analysed the pre-race and post-race questionnaire data using Stata/IC 16.0 for Windows (StataCorp. 2019 Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.), starting with descriptive statistics of participants. Using the following case definition, I calculated sensitivity (the proportion with known SIPE who met the case definition), specificity (the proportion of non-SIPE people that were correctly identified as such), and positive and negative predictive values (the proportion of positive and negative results that are true positive and true negative results, respectively):

An attack of shortness of breath that was out of proportion to the effort being put in, during or immediately after swimming, AND they do not believe it was caused by inhaling water, AND it did not occur immediately on entering the water.

I tested criterion validity using people who had received a previous diagnosis of SIPE as the gold standard. The aim was to determine whether the group who had been diagnosed with SIPE gave different responses to the questionnaire than those known not to have had SIPE (including those with other cardiorespiratory conditions). I planned to use Chi square to determine criterion validity (or Fisher's exact test if expected cell frequencies were <5 in crosstabs).

I had intended to use a test-retest approach using a 2-4 week time lapse to investigate the reliability of the questionnaire items, however, the very short time period between online testing and the first triathlon event at which the survey was going live, meant there was not enough time to do this.

I studied the responses from the feedback questionnaires to identify issues regarding questionnaire usability, understandability and acceptability of questions and appropriateness of response options. Questions were then revised, ready for cognitive interviews.

In order to determine criterion validity, an apriori sample size calculation suggested I needed to include at least six people who had been diagnosed with SIPE, and 18 people who had not, to detect a 70% difference in the proportion that said yes to the right answers (90% in the SIPE group and 20% in the non-SIPE group) with 80% power.

Recruitment of participants was done through convenience sampling. I contacted local triathlon clubs and outdoor swimming clubs via Facebook and through personal contacts. For criterion validity tests, I needed to recruit people who had ever been formally diagnosed with SIPE. This was done by specifically targeting Facebook posts to people who had previously received a medical diagnosis of the condition. All participants were offered an incentive (£5 for doing online tests and £30 for cognitive interviews), were provided with an information sheet (see Appendix 6a) and consent form to sign (Appendix 7).

4.2.3.3 Cognitive interviews

The aim of the cognitive interviews was to ensure that items were interpreted in the way intended and to detect where wording and/or response options were difficult to understand or ambiguous. I used the methods described by Willis (2005, pp. 42–50). The interviews were semi-structured, carried out in person or by telephone, and were recorded (see Appendix 11 for interview schedule). As a trained interviewer, I read aloud each item from the two draft questionnaires and asked participants to answer while 'thinking aloud'. Verbal probing was also used to identify any potential issues. Examples include:

- What were you thinking of when you answered the question?
- I noticed you hesitated before you answered – what were you thinking about?
- What were you basing your answer on?
- Were any parts of the question confusing or difficult to understand?
- Was that easy or difficult to answer? Why was that?
- How did you feel about answering this question?
- Were the response options appropriate?

Following the interviews, recordings were transcribed and any identified issues with items were addressed. The process was iterative, using three rounds of two interviews, with revisions being made after each round.

4.2.3.4 Expert review

The expert review formed part of the content validity testing. Seven SIPE experts/clinicians were asked to take part in the expert review process. Appendix 7 includes the participant consent form that was used. I created a form based on the Questionnaire Appraisal System-1999 (Willis and

Lessler 1999) and emailed it to the experts for completion. The form used on a subset of key questionnaire items designed to detect cases of SIPE and identify potential risk factors (see Appendix 12). It requested feedback for each questionnaire item based on the following criteria: instructions, clarity, assumptions, knowledge or memory, sensitivity or bias, response and other issues. The form also asked for feedback on the proposed case definition and method of case ascertainment. The feedback was used to further refine items in terms of instructions, wording and response options.

4.2.3.5 Field tests

After discussions with the organisers of triathlons at Hever Castle, I was granted permission to carry out my survey using competitors of their events. I decided to use their first event, Hever Castle Festival of Endurance, as a field test for the questionnaires. I developed my data collection protocol and received ethical approval from University of Kent SRC ethics committee (SRCEA id 237) (see Appendix 4b). I launched the pre-race questionnaire followed by the post-race questionnaire soon after. The results of these tests helped to identify and correct any remaining problems regarding the usability of the questionnaires.

4.3 Results

4.3.1 Questionnaire items

The pre-race questionnaire included questions on case definition and symptoms of SIPE, long term risk factors and demographics (see Appendix 8). The post-race questionnaire referred to a particular swim and included questions on case definition and symptoms of SIPE, medical attention received, and swim related factors such as swimming distance, water temperature, wetsuit use, pre-swim drinks, nervousness/anxiety during swimming and exertion levels (see Appendix 9). Case definition questions are included in Table 12.

4.3.2 Preliminary pilot tests

Three colleagues took part in preliminary testing to highlight any issues around understandability and clarity of the wording and response options, and the usability of the online questionnaire. Feedback was positive with no issues raised.

4.3.3 Online tests

4.3.3.1 Participants

I recruited 25 adult outdoor swimmers to take part in online questionnaire testing. This included ten people previously diagnosed as having experienced an episode of SIPE, eight people who had never been diagnosed with SIPE and had no cardiorespiratory conditions, and seven people who had never been diagnosed with SIPE and suffered from a cardiorespiratory condition.

Descriptive statistics for swimmers who took part in online testing of the questionnaires are shown in Table 10. Over three quarters of participants were aged 40–59, 60% were men, and all were of White ethnicity, apart from one who had a mixed ethnic background. The majority of participants lived in the South East or London and over half of participants were sea swimmers. Health conditions affecting participants included asthma, nasal allergies, hypertension, heart conditions and depression. Fisher’s exact test results showed there were no differences between the groups in age, sex or ethnicity ($p>0.05$).

Table 10: Descriptive statistics for participants of online testing of questionnaires

Variable	Group		Total (%)
	SIPE (*n*)	**Non-SIPE (*n*)**	
Total	10	15	25 (100.0)
Age groups			
30-39	0	2	2 (8.0)
40-49	5	6	11 (44.0)
50-59	3	5	8 (32.0)
60-69	2	2	4 (16.0)
Sex			
Female	6	4	10 (40.0)
Male	4	11	15 (60.0)
Ethnic group			
White	10	14	24 (96.0)
Mixed	0	1	1 (4.0)
Region of residence			
South East & London	4	15	19 (76.0)
Other	6	1	6 (24.0)
Smoking status			
Non-smoker	10	14	24 (96.0)
Smoker	0	1	1 (4.0)
Health conditions			
Asthma	2	3	5 (20.0)
Nasal allergy	2	3	5 (20.0)
Hypertension	2	1	3 (12.0)
Heart condition	1	4	5 (20.0)
Depression	0	1	1 (4.0)
None	4	6	10 (40.0)

4.3.3.2 Sensitivity, specificity, positive predictive value, and negative predictive value

I realised that the case definition questions would have performed perfectly in detecting SIPE because one of them asked if a diagnosis of SIPE had ever been received. However, I wanted to test how well the rest of the case ascertainment questions worked since most people who experience SIPE do not see a doctor, so I excluded responses to the question asking if a doctor thought the SOB was due to SIPE.

The case definition questions included in Table 12 were able to correctly identify eight out of the 10 known SIPE positives (true positives), indicating a sensitivity of 80%, and all 15 non-SIPE cases (true negatives), suggesting a specificity of 100% (see Table 11). Two false negatives were identified, both of which were due to the respondents saying they believed the SOB may have been caused by breathing in water (even though they had been told by a doctor it may be due to SIPE). I considered changing the case definition to include respondents who had aspirated water, however, at the time the questionnaire was being developed (2019), the majority of SIPE case definitions used by researchers required the SOB to be in the absence of water aspiration. A positive predictive value of 100% suggested there was a very high probability the respondent had experienced SIPE if the questionnaire identified it. The negative predictive value of 88% showed the probability of identifying true negatives was high.

4.3.3.3 Criterion validity

Table 11 shows the case definition question responses given by participants who had been diagnosed with SIPE compared to those who had not. A Fisher's exact test indicated there was a significant difference in the responses of the two groups (p<0.001), which suggests the questionnaire was successfully able to differentiate between people who have had SIPE, and those who have not or those who have other cardiorespiratory conditions. I considered using a receiver operating curve analysis approach, however, the questionnaire testing sample size of 25 was too small and would have led to: (1) an unstable curve where small changes in predictions could cause large changes in the curve; and (2) an AUC (area under the curve) estimate with wide confidence intervals which would have made conclusions unreliable.

Table 11: Questionnaire responses given by participants with or without a SIPE diagnosis

Questionnaire responses	**SIPE diagnosis**	**No SIPE diagnosis**	**Total**
SIPE	8	0	8
No SIPE	2	15	17
Total	10	15	25

4.3.3.4 Revisions to questionnaires following online tests

Tables 12, 13 and 14 detail the changes that were made to wording and response options following the online tests. One respondent who had been diagnosed with SIPE thought they may have aspirated water, which called into question my case definition that specifically excluded swimmers who had inhaled water. Another respondent who had experienced SOB selected the option that said they did not experience SOB because they felt it was not unexpected because the water was very cold. The need to include the term SIPE as well as pulmonary oedema in response options was raised by an online testing participant. It also became clear during online questionnaire testing that the question that asked “Do you currently have any of the following health conditions? needed to differentiate between health conditions that had been formally diagnosed and those which the respondent thought they might have. As a result, the question was replaced by two separate questions; one asking about medical diagnoses, and another about conditions the respondent thought they may have had (see Table 14).

4.3.4 Cognitive interviews

I recruited six cognitive interviewees, four of whom also took part in questionnaire tests. Cognitive interview participants included two people who had been diagnosed with SIPE, three who suffered SOB during swimming but had not been diagnosed with SIPE, and one who had not experienced SOB during swimming.

Issues raised in cognitive interviews regarding SIPE case definition, symptoms experienced and medical history questions, as well as resulting changes are detailed in Tables 12, 13 and 14. Similar to the online tests, one interviewee who had experienced SIPE believed they had aspirated water, which raised concerns over my case definition. Another interviewee revealed the phrase “breathing in water” was ambiguous and could be interpreted as “breathing out in the water”. In response, I changed the wording to “inhaling water”. I also added a response of cold shock to the question about attribution of SIPE, following a suggestion from an interviewee. The lack of clarity over the reference period for the question about SIPE symptoms was also raised as an issue, so I amended the wording (see Table 13 for details).

Other feedback from cognitive interviewees suggested adding a question for ex-smokers which asked how long ago they quit smoking. The pre-race questionnaires included two questions about alcohol consumption habits in the previous 12 months. An issue with the reference period of 12 months was raised by one cognitive interviewee, since drinking habits can vary greatly depending on the time of year or whether the individual is in training. I therefore changed the reference period to six months to try to reduce this variation and make the question more straightforward to answer.

One cognitive interviewer suggested improving the clarity of inclusion criteria by specifying the respondent should include training swims in their answer to questions about outdoor swimming habits. I received feedback that the question asking about perceived effort levels at the time during swimming was difficult to answer, because effort levels varied during their swim. Therefore, I changed the question so it enquired about maximum effort levels and provided response options ranging from 0 to 100%.

In response to a cognitive interviewee who was rescued from the water in a semi-conscious state, I changed the wording of one question from "Did you seek medical advice" to "Did you receive any medical attention". I also added questions asking how soon after the SOB started did the respondent receive medical attention, whether they had completed their planned swim distance, and if not, the distance they swam on that occasion.

4.3.5 Expert reviews

I received three responses from the experts that were contacted. This included two SIPE experts Dr Courtney Kipps (Consultant in Sports and Exercise Medicine and Principal Clinical Teaching Fellow at the Institute of Sport, Exercise and Health, UCLH) and Dr Ruth Williamson (Consultant Radiologist and Deputy Chief Medical Officer at University Hospitals Dorset), as well as clinician Dr Naren Srinivasan (General Practitioner & Clinical Research Fellow at the University of Kent).

I did not include a scoring matrix in my expert review forms, therefore I was unable to carry out a quantitative assessment of content validity. Feedback received by experts regarding case definition, SIPE symptoms and medical history questions as well as changes made in response to these are summarised in Tables 12, 13 and 14.

One expert reviewer felt the phrase “attack of shortness of breath” should be changed because they believed the onset of SIPE could be gradual. Other suggestions included clarifying the reference period in several questions, rearranging some of the wording to improve clarity, and making terminology more consistent e.g. use either shortness of breath or breathlessness, but not both. Expert reviewers also recommended improving the clarity of response options for the medical history questions by defining medical terms and changing some of the wording (see Table 14). Suggested improvements included splitting the first medical history question into two separate questions; one asking about diagnosed medical conditions, and the other about conditions that may not have been officially diagnosed, and amalgamating the second question about medical history into this question. In response to one expert’s comments I added a SIPE symptom question asking about the colour of any phlegm, froth or fluid that was coughed up (see Table 13 for full details).

4.3.6 Field tests

I made some changes to the online questionnaires following the field tests of the pre-race questionnaire at Hever Festival of Endurance. Firstly, I ensured the online questionnaires were compatible with mobile phones after an early respondent reported issues with completing the questionnaire on their phone. I also decided to move some of the information contained in the participant information sheet to the beginning of the questionnaire, to make the process of completing the questionnaire more efficient.

Table 12: Results of testing of case definition questionnaire items

Wording used in online tests	Issues raised in online tests	Wording used in cognitive interviews	Issues raised by cognitive interviewees	Wording used for expert reviews	Issues raised by expert reviewers	Final wording for field tests
During or immediately after swimming, have you ever experienced an attack of shortness of breath that seemed out of proportion to the effort you were putting in? Yes/No	One respondent said no because they thought it was not unexpected due to the cold temperature of the water	No change	Respondents said 'no' if they thought SOB was due to panic or cold temperature at start of swim	No change	• Onset of SIPE can be very gradual, therefore the use of 'attack' may mislead participants and lead to false negatives • Possible recall failure if symptoms were mild • Rearrange wording to improve clarity	Have you ever had shortness of breath during or straight after swimming outdoors that was out of proportion to the effort you were putting in? Yes/No
At the time of your most recent episode of breathlessness, do you believe it was caused by breathing in water? Yes/No	One swimmer who was diagnosed with SIPE thought he had breathed in some water	No change	• 'Breathing in water' could be interpreted as breathing out in water • One swimmer who had SIPE believed aspirating water contributed to it. • Suggested additional response options of 'partially' and 'don't know'	At the time of your most recent episode of breathlessness, do you believe it was caused by inhaling water? Yes/No	• Change 'inhaling' to 'breathing in', 'unintentionally inhaling' or 'choking on water' • Change 'do you believe' to 'do you recall' • Reference period not well specified i.e. 'did' you believe or 'do' you believe? Not clear if referring to the SOB that was 'out of proportion' or any type of SOB • Use consistent terminology i.e. either shortness of breath or breathlessness • Possible recall failure	The next few questions are about the last time you experienced shortness of breath during or straight after swimming outdoors, that was out of proportion to the effort you were putting in. Do you believe it was caused by inhaling water? Yes/No/Partially: give details/Don't know
Did the symptoms occur immediately on entering the water i.e. within seconds? Yes/No	None	No change	None	At the time of your most recent episode of breathlessness, did the symptoms occur immediately on entering the water i.e. within seconds? Yes/No	• Use response options of immediately (within seconds), later during the swim, after the swim. • Unclear reference period • Possible recall failure	When did the shortness of breath start? Immediately (within seconds of entering the water/Later during the swim/After the swim

<table>
<tr><th>Wording used in online tests</th><th>Issues raised in online tests</th><th>Wording used in cognitive interviews</th><th>Issues raised by cognitive interviewees</th><th>Wording used for expert reviews</th><th>Issues raised by expert reviewers</th><th>Final wording for field tests</th></tr>
<tr>
<td>Did a doctor tell you or do you think that the breathlessness was due to any of the following? Tick all that apply.
• Panic attack
• Smoking
• A nasal allergy i.e. hay fever
• Asthma
• Pulmonary oedema
• Pulmonary embolism
• Heart failure
• Other reason: Please specify</td>
<td>Include SIPE to pulmonary oedema response option</td>
<td>No change</td>
<td>Add cold shock response as an option.</td>
<td>Did a doctor tell you or did you think the breathlessness was due to any of the following? Tick all that apply.

<table>
<tr><th></th><th>Medical diagnosis</th><th>Self-diagnosis</th></tr>
<tr><td>Panic attack</td><td>☐</td><td>☐</td></tr>
<tr><td>Smoking</td><td>☐</td><td>☐</td></tr>
<tr><td>A nasal allergy i.e. hay fever</td><td>☐</td><td>☐</td></tr>
<tr><td>Asthma (including exercise-induced)</td><td>☐</td><td>☐</td></tr>
<tr><td>Cold shock response</td><td>☐</td><td>☐</td></tr>
<tr><td>Pulmonary oedema or SIPE</td><td>☐</td><td>☐</td></tr>
<tr><td>Pulmonary embolism</td><td>☐</td><td>☐</td></tr>
<tr><td>Heart failure</td><td>☐</td><td>☐</td></tr>
</table></td>
<td>• Split item into ‘Did you seek medical advice’, ‘What did the doctor tell you was the cause of your SOB’, and ‘What do you think was the cause of your symptoms’
• Add ‘COPD and other’ to response options
• Replace ‘nasal allergy i.e. hay fever’ with ‘allergic conditions such as hay fever’
• Replace doctor with health professional
• Possible recall failure
• Lack of clarity i.e. multiple ways to interpret question</td>
<td>Do you think the shortness of breath was due to any of the following? Tick all that apply.
• Panic attack
• Smoking
• Allergies such as hay fever
• Cold shock response
• Other reason: please specify
• None of the above

You selected [response option]. Did you see any health professional (e.g. doctor, nurse, paramedic) about this? Yes/No

Did they think the shortness of breath was due to [response option]? Yes/No

Probes added after medical history questions:

Do you think the shortness of breath was due to [diagnosed condition]? Yes/No/Partly/ Don't know

Did a health professional think it was due to [diagnosed condition]? Yes/No</td>
</tr>
</table>

SOB = shortness of breath; COPD = chronic obstructive pulmonary disease

Table 13: Results of testing of questionnaire items relating to symptoms experienced during SIPE episode

Wording used in online tests	Issues raised in online tests	Wording used in cognitive interviews	Issues raised by cognitive interviewees	Wording used for expert reviews	Issues raised by expert reviewers	Final wording for field tests
Was this shortness of breath accompanied by any of the following symptoms? Tick all that apply. • Whistling or crackling sound in the chest • A cough not related to a cold or other respiratory infection • Coughing up phlegm or fluid • A feeling of tightness in your chest • Other: Please specify		No change	Clarify reference period	Was your most recent episode of breathlessness accompanied by any of the following symptoms? Tick all that apply. • Whistling or crackling sound in the chest • A cough not related to a cold or other respiratory infection • Coughing up phlegm or fluid • A feeling of tightness in your chest • Other: Please specify	• Consider including wheezing to response options, separate whistling from crackling, and add froth/foam to 'coughing up phlegm or fluid' • Add response option of 'a cough not related to a pre-existing respiratory condition' • Ask about colour of phlegm • No clear reference period • Possible recall failure	Did you have any other symptoms at the time? Tick all that apply. • Wheezing or whistling in the chest • Crackling sound in the chest • An unexplained cough • Coughing up phlegm, froth or fluid • A feeling of tightness in your chest • Other: Please specify • No other symptoms What colour was the phlegm, froth or fluid? • Yellow • White • Brown • Pink, red or blood stained • Other: Please specify • Don't know

Table 14: Results of testing of questionnaire items relating to medical history

<table>
<tr><th>Wording used in online tests</th><th>Issues raised in online tests</th><th>Wording used in cognitive interviews</th><th>Issues raised by cognitive interviewees</th><th>Wording used for expert reviews</th><th>Issues raised by expert reviewers</th><th>Final wording for field tests</th></tr>
<tr>
<td>Do you currently have any of the following health conditions? Tick all that apply.
• High blood pressure
• Diabetes
• Asthma
• Nasal allergy i.e. hay fever
• Raynaud's syndrome
• Heart failure or other heart trouble: Please specify
• Other: Please specify
• No health conditions</td>
<td>Need to differentiate between conditions that are/are not formerly diagnosed</td>
<td>Has a doctor diagnosed you with any of the following health conditions? Tick all that apply
• High blood pressure
• Diabetes
• Asthma
• Nasal allergy i.e. hay fever
• Raynaud's syndrome
• Heart failure or other heart trouble: Please specify
• Other: Please specify
• No health conditions

Do you think you have any of the following health conditions? Tick all that apply.
• Asthma (including exercise-induced)
• Nasal allergy i.e. hay fever
• Raynaud's syndrome
• Poor circulation
• Other: Please specify
• No health conditions</td>
<td>None</td>
<td>Do you currently have any of the following health conditions? Tick all that apply.

<table>
<tr><th></th><th>Medical diagnosis</th><th>Self-diagnosis</th></tr>
<tr><td>High blood pressure</td><td>☐</td><td>☐</td></tr>
<tr><td>Diabetes</td><td>☐</td><td>☐</td></tr>
<tr><td>Asthma (including exercise induced)</td><td>☐</td><td>☐</td></tr>
<tr><td>Nasal allergy i.e. hay fever</td><td>☐</td><td>☐</td></tr>
<tr><td>Raynaud's disease</td><td>☐</td><td>☐</td></tr>
<tr><td>Heart failure or other heart trouble: Please specify</td><td>☐</td><td>☐</td></tr>
<tr><td>Other: Please specify</td><td>☐</td><td>☐</td></tr>
<tr><td>No health conditions</td><td>☐</td><td>☐</td></tr>
</table></td>
<td>Separate into two questions; have you ever been diagnosed/ diagnosed in last 12 months and, do you think you may have any of the following?
• Define Raynaud's disease
• Vague response categories i.e. heart trouble
• Replace 'nasal allergy i.e. hay fever' with 'allergic conditions such as hay fever'
• Consider adding COPD and cancer
• Overlapping categories i.e. possible to select no health condition and any of the health conditions</td>
<td>Has a health professional ever diagnosed you with any of the following health conditions?
• Asthma
• Chronic bronchitis
• COPD (chronic obstructive pulmonary disease)
• Emphysema
• Heart condition: please specify
• Pulmonary embolism (blood clot in the lung)
• Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs)
• High blood pressure
• Diabetes
• Pneumonia
• Other: please specify
• None of the above

Do you think you have ever had symptoms of any of the following health conditions?
• Asthma (including exercise induced)
• Allergies such as hay fever
• Raynaud's disease (reduced blood flow to fingers and toes in response to cold)
• Panic attack
• None of the above</td>
</tr>
</table>

Wording used in online tests	Issues raised in online tests	Wording used in cognitive interviews	Issues raised by cognitive interviewees	Wording used for expert reviews	Issues raised by expert reviewers	Final wording for field tests
Have you ever had any of the following? Tick all that apply. • Panic attack • Pulmonary oedema • Pulmonary embolism • Angina • Pneumonia • None of the above	None	No change	None	No change	• Define pulmonary oedema and pulmonary embolism • Not sufficiently different to previous question	Amalgamated with above medical condition questions.

COPD = chronic obstructive pulmonary disease

4.4 Discussion

This chapter describes the development of two questionnaires to detect cases of SIPE and gather information on outcomes, possible risk factors and background data. Online tests suggested questionnaire items were valid, as well as sensitive and specific. The instrument successfully collected the information that was required. Cognitive interviews and the expert review process identified some important issues that needed to be addressed in terms of understandability that may not have been discovered otherwise. The resulting questionnaires enabled the collection of a comprehensive dataset during the next phase of the study, on which to conduct the intended analyses. The iterative nature of the testing process meant the final version of the questionnaires were the product of the validation process, but were not themselves fully validated.

4.4.1 Online tests

The participants of online tests were a heterogeneous group, including male and female triathletes and sea swimmers of varying ages, which was representative of the target population. This helped to ensure the questions were relevant and applicable to a wide range of open water swimmers. The online testing process highlighted a weakness of the case ascertainment questions since two of the known SIPE cases thought they had aspirated water. I considered changing the case definition so it did not exclude aspiration of water, however at the time, many SIPE case definitions used in existing research papers specified that SOB was to be in the absence of water aspiration. Since then, however, new research has been published and understanding of the condition has evolved. For example, Hårdstedt *et al* (2020) carried out a study of competitors of an open water swimming event in Sweden, with the aim of identifying diagnostic criteria for SIPE based on symptoms and clinical examination that could be applied easily. The authors used onsite lung ultrasound scans to confirm a diagnosis of SIPE and found the proportion of patients who reported water aspiration was the same among cases and non-cases. They concluded that aspiration of water should not be an exclusion criterion for SIPE.

4.4.2 Cognitive interviews

The in depth cognitive interviews proved to be an extremely useful way of obtaining detailed feedback from participants. For example, one interviewee highlighted an important issue with interpretation of the phrase “breathing in water” in the case ascertainment questions, which would otherwise have been missed. This enabled me to change the wording to avoid confusion by subsequent respondents. Interviewees also suggested adding questions to collect more information about smoking, and highlighted the issue of having such a long reference period of 12 months when asking about drinking habits.

4.4.3 Expert review

The feedback received from experts helped to further refine key questionnaire items. I ensured the data collection forms I developed for this purpose were user friendly and an efficient way for the three experts to highlight potential issues. Much of the feedback highlighted issues with the case ascertainment questions, such as lack of clarity of wording, inconsistent terminology, the reference period not being well specified, or the possibility of recall failure.

4.4.4 Limitations

The questionnaires were developed to the highest possible standard within a tight timescale during the lead up to field tests at Hever Festival of Endurance in early July 2019. Given more time, the questionnaire items could have been further refined, using additional participants and further rounds of testing and validation, however, this would have risked missing the opportunity for field tests. Furthermore, the additional effort required might not have resulted in significant improvements to the quality of the questionnaires.

The questionnaires were developed and tested using a small sample of open water swimmers who were predominantly middle-aged, White and from the South East or London. This may make them less generalizable to other demographic groups from other geographical areas, although the proportion from non-White backgrounds in my sample was comparable to the sample of swimmers who responded to surveys conducted by Outdoor Swimmer magazine (Outdoor Swimmer 2022; Outdoor Swimmer 2021). There were also differences in the characteristics of the groups used in the criterion validity tests e.g. the SIPE group contained a greater proportion of sea swimmers and the non-SIPE group were more likely to be triathletes. This makes the groups less comparable in many ways, however these differences should not have affected responses to the case ascertainment questions, which were used to assess validity.

Experts were only asked to review a subset of nine questionnaire items, in order to limit the time commitment required and increase the likelihood of forms being fully completed and returned. This means many of the questions related to outcomes and possible risk factors did not go through the expert review process. Only three experts took part in expert reviews, which limited the amount of feedback received. I did not include a scoring matrix in my expert review forms, which meant I was unable to carry out a quantitative assessment of content validity i.e. the degree to which the questionnaire items were relevant to and representative of the predefined constructs.

The feedback received during the questionnaire testing process was sometimes inconsistent, so required an element of judgement to deal with. This would have introduced an additional element of bias into the process.

My initial plans included conducting test retest reliability tests as measures of internal validity i.e. to measure the consistency of responses when participants complete the questionnaire on two different occasions. However, the tight timescales I was working within did not allow time for this to take place.

The questionnaire could have been improved by including additional questions relating to the severity of SOB and other symptoms, swimming stroke used, and details of the swimming environment i.e. type of open water and conditions at the time. However, this would have made the questionnaire even longer, which would have increased the likelihood of questionnaires being left unfinished by respondents.

My approach to testing criterion validity using people with a previous diagnosis of SIPE as the gold standard may have been flawed since there is no standard case definition or clear diagnostic criteria for SIPE, which means that many people with SIPE never receive a diagnosis, and some of those who get a diagnosis may not have actually experienced SIPE.

4.5 Conclusions

As far as I am aware, these questionnaires are the first instruments designed specifically for detecting cases of SIPE and gathering information on risk factors and outcomes that have been systematically tested and refined. Although the final version of the questions were not themselves fully validated, they were the product of a robust testing, refining and validation process. Core questionnaire items were improved to ensure they were understandable and acceptable to respondents, and collected the required data. The SIPE case definition I used was highly sensitive and specific, and showed high positive and negative predictive values. Criterion validity was also high, meaning the case definition successfully differentiated between swimmers who had experienced SIPE and those who had not, or who had other cardiovascular health conditions. The questionnaires that I developed enabled me to collect a high quality dataset on which to base the subsequent analytical phases of this PhD study.

Chapter 5: Occurrence of SIPE

5.1 Introduction

The purpose of this chapter is to report two linked studies undertaken to investigate the incidence of SIPE and the prevalence of ever having experienced SIPE in outdoor recreational swimmers in the UK. This will provide evidence to guide research on the prevention, treatment and identification of people at risk and will also inform policy on safety at open water swimming events and recommendations to outdoor swimmers.

The research to date does not provide reliable estimates of either the incidence of SIPE or the prevalence of ever having had an episode of SIPE. My systematic review found only one study that gave insight into the prevalence of ever having had SIPE among competitive outdoor swimmers, which indicated that about 1.4% of triathletes had experienced an attack of SIPE in their lifetime (Miller, Calder-Becker and Modave 2010). However, the study was limited by the use of a self-completed non-validated questionnaire, a narrow case definition and a very low response rate of 1.3%. Eight studies reported an incidence of SIPE ranging from 0.01% of UK triathlons raced over five years, to 26.7% of time trials in the sea around Israel. However, the studies were very different in terms of characteristics of participants and length of time over which SIPE episodes were recorded, so were unreliable for estimating frequency of the condition.

For my prevalence study I chose to define cases as people who reported having experienced SIPE at some point in their lifetime i.e. lifetime prevalence of ever having experienced an attack of SIPE. I chose not to refer to a specific time period such as the last year, to maximise the chances of identifying sufficient SIPE cases to carry out the intended analyses for the study (and subsequent case-control study). Therefore, for this study, prevalence means the proportion of outdoor swimmers that report having *ever* been diagnosed with SIPE or experienced symptoms suggestive of SIPE.

The established method for determining prevalence is to identify a suitable population, select a sampling frame and sample from it (ideally randomly). Then a case definition is used to identify all cases from the sample. This is more straightforward with conditions that are logged in medical records, however, this is not often the case with SIPE; even where there is a record of SIPE, it is very difficult to identify due to the lack of a specific ICD diagnosis code. Therefore, I chose to identify cases through conducting a survey of the population of interest.

Defining the population of interest for this study was difficult because there is no readymade sampling frame, such as a register of outdoor swimmers in the UK. Therefore, I decided to use competitors of races that involved open water swimming at three large triathlon events, as this provided access to thousands of regular outdoor swimmers who could be surveyed relatively easily. I also carried out an additional survey of outdoor recreational swimmers in the UK who swim regularly. This meant the study participants were a very heterogeneous group, ranging from serious endurance athletes to regular recreational sea swimmers. As is often the case with prevalence studies, there was the risk of response bias whereby people may have been more likely to complete the survey if they had had the condition in question.

Incidence is defined as the occurrence of new cases in a population over a specified time period. In most circumstances incidence refers to the first occurrence of the condition, however, SIPE is an acute condition that tends to resolve fairly quickly, therefore I defined incidence as any cases that occurred during a specific time period, regardless of whether the individual had previously experienced SIPE or SIPE-like symptoms. Incidence is usually measured through cohort studies that identify the population of interest who do not have the condition and follow them up over time to find out if they develop it. Due to the limited resources and time associated with a PhD study, my population of interest was competitors of open water swimming races that were surveyed for the prevalence study. I conducted pre and post-race surveys of competitors to identify prospectively cases of SIPE. For incidence studies such as this, there is the risk of participants being lost to follow-up, which can cause bias and threaten the validity of the study. However, given the short time period of a matter of weeks between pre- and post-race surveys, this would have been less of a risk. As with the prevalence study, there was also the risk of response bias with the incidence study.

The previous chapter on questionnaire development (chapter 4) sets out the importance of a standardised case definition (set of criteria) for identifying cases of disease in the absence of a clinical diagnosis. I discussed the lack of a standardised case-definition for SIPE and reviewed the variety of case definitions used in previous studies of SIPE. For the prevalence and incidence studies, I chose to use an array of case definitions, ranging from a very broad to narrow set of criteria as a way to detect mild cases of SIPE where symptoms were limited to SOB, as well as more severe episodes which included a cough and sputum:

- SOB immediately, during or after swim in absence of water aspiration
- SOB not immediately in absence of water aspiration
- SOB and cough not immediately in absence of water aspiration
- SOB and coughing up sputum not immediately in absence of water aspiration
- SOB and coughing up pink, red or blood stained sputum not immediately in absence of water aspiration
- SOB during or after swim and evidence of pulmonary oedema on examination

The studies were designed to collect data to answer the following research questions:

- What is the prevalence of *ever* having experienced SIPE in UK outdoor swimmers?
- What is the incidence of SIPE in UK outdoor swimmers?

I also intended to use the data collected to understand risk factors for SIPE (see chapter 6). Chapter 4 provides a detailed explanation of the above research questions.

5.2 Prevalence study methods

The aim of the prevalence study was to estimate the proportion of outdoor swimmers in the UK that have ever been diagnosed with or experienced symptoms suggestive of SIPE in their lifetime.

5.2.1 Study design

I used four online surveys to collect data using the validated questionnaires developed and discussed in chapter 4. This included three surveys of triathlon event competitors and a large survey of outdoor swimmers in the UK.

5.2.2 Population

The population of interest for the prevalence study was adults who regularly swim outdoors in the UK. This is a highly heterogeneous group that includes competitive endurance triathletes, marathon swimmers, year round regular outdoor swimmers, and people that swim outdoors less often and only in the warmer months. For this study, I was most interested in the first three groups of swimmers.

5.2.3 Sample size

I carried out sample size calculations to determine an adequate sample size to estimate the prevalence of SIPE with reasonable precision. By 'reasonable precision' I mean an estimate where 95% confidence intervals are narrow enough to result in a useful estimate of prevalence. For example, if the sample size is too small and confidence intervals are too wide or if the lower confidence interval includes negative values, the resulting estimate of population prevalence will be of limited use. In addition to prevalence estimates, my chosen sample size needed to be large enough to show differences between SIPE sufferers and non-SIPE sufferers in my risk factor study. With regard to SIPE incidence estimates, this study was more exploratory in nature, therefore, I did not take this into account when calculating sample size.

I used the following formula (Daniel 1999) to determine sample size:

$$n = \frac{Z^2 P(1-P)}{d^2}$$

where

n = sample size,
Z = Z statistic for a level of confidence,
P = expected prevalence or proportion,
d = precision

If the conventional 95% confidence interval is used, the Z value is 1.96. Based on the Miller, Calder-Becker and Modave (2010) study of triathletes, the expected prevalence of SIPE is 0.014. I used precision of 0.007 in order to keep confidence intervals reasonably narrow (0.007–0.021). This resulted in a sample size estimate of 1,082 outdoor swimmers.

5.2.4 Sampling frame

Since there is no register of outdoor swimmers in the UK, I had to devise my own sampling frames. I initially chose to survey competitors of three outdoor swimming events in 2019 as this provided a known sampling frame covering a large number of competitive swimmers who could be reached through collaborating with event organisers. Hever Castle triathlon events and London Triathlon, in particular, were chosen based on existing links with the organisers. All are popular events that attract large numbers of entrants from across the South East and include many different races with an element of outdoor swimming. Hever Castle events consisted of the Festival of Endurance on 7th July 2019 and Hever Castle Triathlon on 28th and 29th September 2019. They included triathlons (swim, bike, run), aquabike races (swim, bike), aquathlons (swim, run) and open water swims, as well as duathlons (run, bike, run) and running races. The outdoor swims took place in Castle Lake and River Eden with distances varying from 200m to 10km. London Triathlon took place on 27th July 2019 and included triathlon races with swimming taking place in the Royal Victoria Dock. Swim distances ranged from 400m to 1.5km. Table 15 shows the number of competitors that entered outdoor swimming races at each of the events, which totals almost 9,000.

Table 15: Competitors that took part in races involving outdoor swimming

Event	Number of adult competitors
Hever Castle Festival of Endurance	660
London Triathlon	5,308
Hever Castle Triathlon	2,914
Total	8,882

The sample size achieved from the three triathlon event surveys was only 108 and therefore not sufficient for the prevalence study which required over 1,000 responses. Therefore, I carried out an additional survey aimed at outdoor swimmers who were members of ten outdoor swimmer/ triathlon Facebook groups (see Table 16). This was chosen as a quick and efficient way of accessing a large number of people from the target population and also had the advantage of increasing the exposure of the study through shares and reposts within social media networks. However, it meant the sampling frame was much less well defined than for the swimming races so may have included less regular swimmers that heard about the survey through friends and social media contacts. The outdoor swimming survey targeted an additional 116,000 swimmers (see Table 16) increasing the sample population to over 125,000. However, it may not have reached them all, as some people may have been in more than one group and it is likely to have included some swimmers who were outside the target population group. This could have potential negative impacts on the reliability and validity of the study.

Table 16: Facebook groups where survey invitations were posted

Facebook group	Triathlon/outdoor swimmer group	Public/private group	Group members (*n*)
Ashford Tri Club	Triathlon	Private	128
Deal Tri Club	Triathlon	Private	573
The Triathlon Coach Café	Triathlon	Private	4,100
The Ironman Journey	Triathlon	Private	39,300
Outlaw Triathlon Group	Triathlon	Public	6,200
Outdoor Swimming Society	Outdoor swimmer	Public	60,400
Beyond the Blue	Outdoor swimmer	Private	2,000
Just Swim	Outdoor swimmer	Private	1,300
Seahorse Swim	Outdoor swimmer	Private	1,300
Durley Sea Swims	Outdoor swimmer	Private	875
Total potential views of post			116,176

5.2.5 Sampling methods

SIPE is a relatively uncommon condition, therefore one would expect only a small number of the race competitors to have experienced it. To maximise the chances of finding sufficient cases of SIPE for the study, I used whole population sampling i.e. I included *all* adult entrants to races that involved outdoor swimming.

For the outdoor swimming survey, I used a combination of convenience sampling and snowball sampling. These sampling methods are types of non-probability sampling which mean that not all members of the target population have an equal chance of taking part in the study, unlike probability sampling. They are also limited by the fact they may not reach the whole sample population. As a result, one must be cautious about making generalisations based on the findings, since the sample may not be representative of the population.

A convenience sample is described by Bryman (2016, p. 187) as *"one that is simply available to the researcher by virtue of its accessibility"*. The convenience sampling involved posting survey invitations on Facebook groups of which I was a member (*n*=10) (see Table 16), as well as on the Facebook pages of other individuals (*n*=2). The CHSS twitter account was also used to share links to the surveys.

Snowball sampling is when the researcher uses existing participants to recruit future participants. This means initial contact is only necessary with a small group of people who a part of the target population. My snowball sampling involved encouraging Facebook group members and other survey participants to share the survey invitation posts widely within their personal and professional networks. The tweet that was posted by the CHSS account also included tags and was worded in a way to encourage sharing and retweeting.

5.2.6 Data collection methods

The prevalence study involved four online surveys consisting of three event surveys and an outdoor swimming survey. The event surveys included outdoor swimming race competitors at the following events; Hever Castle Festival of Endurance in early July 2019 ; London Triathlon in late July 2019; and Hever Castle Triathlon in September 2019.

The intention was to collect data on prevalence before people completed their races to understand if they had ever experienced an episode of SIPE. Each event survey included a pre-race questionnaire that was distributed in the four weeks prior to the event. The outdoor swimming survey was carried out between February and April of 2020 and used a very similar questionnaire to identify if a swimmer had previously had an episode of SIPE. Both questionnaires were set up using the Qualtrics online survey tool and contained survey questions that had undergone validation (see chapter 4). The data collection protocol for the event surveys received ethical approval from University of Kent SRC Ethics Committee in June 2019 (SRCEA id 237) (see Appendix 4b). Ethical approval for an amendment to cover data collection in the outdoor swimming survey was approved in November 2019.

I carried out the surveys online due to the following advantages compared to postal surveys:

1. Low cost – Unlike postal questionnaire surveys, online surveys do not incur any costs associated with postage, paper, envelopes and the time needed to stuff envelopes for the

mail-out. The university already held a licence for the online survey software Qualtrics therefore there were no set-up costs.

2. Quicker response – Once the respondent has completed the form, the data is immediately stored, unlike postal surveys where the researcher has to wait for the form to be returned.

3. Filtering – Online survey tools enable automatic skipping using filter questions making the survey quicker and easier for respondents to complete.

4. Better response to open-ended questions – Bryman (2016, p. 235) suggests open-ended questions are more likely to be answered in a web survey and often result in a more detailed response.

5. Better data accuracy – As the data is automatically captured, there is no need for any manual data entry, thereby reducing the likelihood of errors.

However, there are also some disadvantages of online surveys:

1. Lower response rates – Response rates tend to be lower than for postal questionnaires (Shih and Fan 2008).

2. Restricted to those with internet access – However, internet use is now almost universal with a recent Office for National Statistics survey showing that 99% of adults aged 16-44 had used the internet recently (Office for National Statistics 2021). In particular, Facebook use in triathletes was reported to be as high as 73% in a survey of over 5,000 triathletes (Triathlon Industry Association, 2016).

3. Multiple replies – Participants are able to complete the questionnaire more than once. However, it is possible to remove many duplicate responses if personal identifiers such as email address are collected.

5.2.7 Data collection tools

The following is a brief description of the questionnaires used for the prevalence study. See chapter 4 for more detail on the content of the questionnaires.

The pre-race questionnaire was created using the Qualtrics online survey tool and collected data on demographics, previous episodes of breathlessness/SIPE, health conditions, swimming habits and health behaviours (see Appendix 13). The outdoor swimming questionnaire included selected items from the pre and post-race questionnaires (see Appendix 15).

5.2.8 Recruitment of participants

5.2.8.1 Hever Castle Festival of Endurance pre-race survey

Links to the survey were disseminated with the help of the event organiser Castle Triathlon Series. The communications team included in their scheduled pre-race emails to competitors, an invitation to complete the survey (see Appendix 5a), which contained web links to a participant information sheet saved as a publicly accessible document on Google Drive (see Appendix 6c). Links to the online questionnaire were included within the information sheet. These emails were sent out at one month before and two weeks before the event.

Unfortunately, a number of problems were encountered during this initial survey. Firstly, there was a delay in receiving University of Kent ethical approval, which meant the pre-race survey could not be launched until a week after the links had been distributed to competitors. This meant that in the meantime the survey link would not have worked if respondents clicked on it. The start date for the survey was highlighted in the participant information, however, I believe this problem will have almost certainly lost a number of respondents. Another issue that was raised by one respondent was that the first question regarding consent did not work properly on their mobile phone, making it impossible to progress to the next question. I quickly addressed the problem, ensuring the entire questionnaire was compatible with mobile phones.

5.2.8.2 Refinement of survey methods

Before launching the survey at the next event, I used lessons learned from the initial survey to refine the data collection methods to try to increase the number of responses. Firstly, I made some changes to the participant information to make the process of recruitment simpler and more streamlined. Instead of participants having to click a link to a very wordy information sheet and then another link to the survey, I included most of this participant information at the start of the survey and created an eye catching flyer containing only key pieces of information including web links to the survey as well as a QR code (see Appendix 5c for example). The flyer then replaced the participant information sheet that was saved on Google Drive.

Secondly, I used social media to help distribute invitations to participate in the survey. I had not initially planned to do this due to the difficulty it can cause in determining response rates. For example, when posting an invitation on social media platforms, it is difficult to know the exact number of people that have been invited i.e. those that have seen the post, particularly on publicly accessible pages. Instead, I had planned to use email to distribute links to all registered competitors so I could easily calculate the proportion that responded. However, due to the very low number of responses achieved with the first survey, I deemed it necessary to use all available methods to boost the sample size.

5.2.8.3 London Triathlon pre-race survey

Unfortunately, due to a change in the event's organising body from the previous year, I was not able to secure any agreement for survey invitations to be included in emails to competitors or for the organisers to promote the survey in their social media feeds. Therefore, recruitment was done only through posting a survey invitation on the public section of the London Triathlon Facebook page (which was not visible from the main page) and through the CHSS Twitter account (see Appendix 5b for examples of both).

5.2.8.4 Hever Castle Triathlon pre-race survey

For this event, I followed a similar process to the Festival of Endurance pre-race survey, using scheduled emails from the organiser to competitors to invite them to participate in the surveys. As before, the pre-race emails were sent out at one month and at two weeks before the day of the race. In addition to the emails, I used social media to boost the sample size. Posts publicising the surveys which contained a link to the survey and flyer saved on Google Drive, were added to the public wall of the Castle Triathlon Series Facebook group page (similar to the Facebook post in Appendix 5c). This was done nine days before the weekend of the race. The CHSS Twitter account was also used to promote the survey nine days before the event (see Appendix 5c).

5.2.8.5 Outdoor swimming survey

For the survey of outdoor swimmers, I relied mainly on social media for recruitment of participants. Links to the survey were posted on two personal Facebook pages as well as on the 10 triathlon and outdoor swimmer Facebook groups listed in Table 16 (see Appendix 5d). The posts were also shared within personal networks of some of the participants and interested parties, although the exact number of times this occurred is unknown. Tweets promoting the survey were posted by the CHSS Twitter account on the 7th and 13th February 2020 (see Appendix 5d). In addition, Outdoor Swimmer magazine shared links to the survey on Facebook and Twitter. A survey invitation was also included in the University of Kent CHSS Newsletter for Winter/Spring 2020. This was distributed widely through its usual mailing list and was also accessible through the CHSS web pages.

5.2.9 Participant incentives

Evidence suggests that incentives are likely to increase response rates in web surveys. For example, Göritz (2006) carried out a meta-analysis of 32 studies on the impact of incentives on response rates and found that incentives significantly increased the likelihood of people starting the survey (OR 1.19) and completing the survey (OR 1.27). Therefore, I decided to use prize draw incentives (£100 Wiggle vouchers) as a relatively low cost option for encouraging participation.

5.2.10 Data processing and analysis

After the closing date, the results from the pre-race surveys and outdoor swimming survey were exported from Qualtrics into Excel and saved in password protected csv files. I also included some prevalence questions in the Hever Castle post-race survey, so these data were also exported and saved as csv files. The data files were then imported into Statafor Windows (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.) and appended into a single dataset of pre-race variables (see flowchart in Figure 2). Responses where the first question had not been answered were excluded from the analysis, as were duplicate responses identified through email addresses. If an email address appeared more than once and age group and sex were also the same, the respondent was assumed to be the same person. The less complete responses, or the later responses, if both are similarly complete, were excluded from the analysis.

These data were then cleaned and coded in preparation for analysis. I produced descriptive statistics of the following variables: age band, sex, ethnicity, region of residence, smoking status and type of race.

Prevalence of SIPE was calculated using the following equation:

$$\text{Prevalence} = \frac{\text{Number of respondents who had experienced symptoms suggestive of SIPE}}{\text{Total number of respondents}} \times 100$$

I used a number of differing SIPE case definitions, from the broadest to the narrowest, to identify from pre-race data swimmers who had ever experienced suspected episodes of SIPE.

5.3 Incidence study methods

The aim of the incidence study was to collect data after three outdoor swimming events to estimate the proportion of competitors that experienced SIPE during or after their race, regardless of whether they had suffered from SIPE previously.

5.3.1 Study design

The study was a survey of people who had recently completed outdoor swimming events.

5.3.2 Population

The population of interest was competitive adult triathletes and endurance open water swimmers.

5.3.3 Sample size

The primary purpose of this study overall was to estimate prevalence of ever having had SIPE, but I used this opportunity to try to estimate incidence as well. I recognised that to get an accurate and precise estimate of incidence I would likely need a very large sample of outdoor swimmers with a lot of exposure i.e. a lot of time spent swimming in open water. To get an idea of how large a sample of outdoor swimming race competitors I would need, I carried out sample size calculations based on a high estimate of incidence of 5% per swimming race, although the true figure may be much lower. I used the Daniel (1999) sample size formula with a Z value of 1.96 and expected proportion of 0.05 (see section 5.2.3). I chose a precision value of 0.01 to aim for confidence intervals of between 0.04 and 0.06. The resulting sample size estimate was 1,825 outdoor swimming race competitors. This would not have been possible to achieve given my three chosen events had a total of 8,882 swimming race competitors and it would have required a response rate of over 20%, assuming all competitors received survey invites. In reality, the expected incidence was likely to be lower than 5%, therefore, the actual sample size required will have been much higher. To achieve this would have been beyond the scope of a PhD study and would have required research funding.

5.3.4 Sampling frame

The sampling frame was people who had recently completed outdoor swimming events at Hever Castle Festival of Endurance, Hever Castle Triathlon and London Triathlon in 2019. Section 5.2.4 describes the events and number of competitors in more detail. The total sample population was around 9,000 competitors.

5.3.5 Sampling methods

I used whole population sampling as detailed in the section 5.2.5 to maximise the likelihood of finding cases of SIPE.

5.3.6 Data collection methods

The incidence study involved three online surveys carried out at the same events as the prevalence study i.e. Hever Castle Festival of Endurance, Hever Castle Triathlon and London Triathlon in 2019. The intention was to collect data on incidence after people had finished their races to understand if they had experienced an episode of SIPE during or after their swimming race. Each event survey included a Qualtrics post-race questionnaire that was distributed to competitors within 10 days of the event. As with the pre-race surveys, the post-race questionnaire included validated survey questions (see chapter 4) and the protocol received ethical approval from University of Kent SRC Ethics Committee (SRCEA id 237) (see Appendix 4b).

5.3.7 Data collection tools

The incidence study used data collected through the Qualtrics post-race questionnaire. The main purpose of the post-race questionnaire was to identify cases of SIPE that occurred during or after swimming races. It collected data on the race that was entered, health conditions, health behaviours and unexplained breathlessness experienced during and after the swimming race (see Appendix 14).

5.3.8 Recruitment of participants

Participants were recruited using email, social media, posters, the CHSS newsletter and in person.

5.3.8.1 Hever Castle Festival of Endurance post-race survey

Two days after the event the communications team sent a post-race email to all competitors. As with the pre-race survey, the email included an invitation to take part in the post-race survey and a link to the participant information sheet (see Appendix 6d), which contained links to the post-race questionnaire. In addition, for those pre-race survey respondents who had agreed to be contacted by the research team, a week later I sent an invitation email with a link to the post-race information sheet.

5.3.8.2 London Triathlon post-race survey

As mentioned in the prevalence section, I was not able to get survey invitations included in emails to London Triathlon competitors or for the organisers to publicise the survey. Therefore, recruitment was done only through Facebook posts on the public section of the London Triathlon Facebook page and the CHSS Twitter account (see Appendix 5b for example).

5.3.8.3 Hever Castle Triathlon post-race survey

Post-race emails were sent out by the event organisers after the race, however, unfortunately the survey invitation was accidently omitted from the emails. Facebook posts which promoted and included a link to the survey and flyer, were added to the public wall of the Castle Triathlon Series Facebook page at three and ten days after the race. The organisers agreed to share the final post on the main page of the Castle Triathlon Series Facebook group page as well as the Hever Castle Triathlon 2019 event Facebook page, where it would be more visible. In addition, the CHSS Twitter account was used to publicise the survey after the weekend of the event (see Appendix 5c).

In order to recruit more participants I travelled to the event on Saturday 28th September. I displayed posters promoting the surveys (large version of the flyer in Appendix 5c) across the main public areas of the site and approached competitors after their races to invite them to complete the online post-race questionnaire on an iPad.

5.3.9 Participant incentives

Similar to the pre-race surveys, I used prize draw incentives (£100 Wiggle vouchers) to encourage participation in the post-race surveys.

5.3.10 Data processing and analysis

Incidence data collected from the post-race surveys were exported into Excel from Qualtrics and saved in password protected files. Duplicate responses and those where the respondent did not progress beyond the first question were excluded from the analysis. Data from the three post-race surveys were appended into a single data file of post-race variables (see flowchart in Figure 2) and imported into Stata/IC 16.0 for Windows (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.). These data were then cleaned and coded in preparation for analysis. Descriptive analysis was carried out on the following variables: age band, sex, ethnicity, region of residence, smoking status and type of race.

Incidence of SIPE was calculated using the following equation:

$$\text{Incidence} = \frac{\text{Number of respondents who had suspected SIPE during/after swimming race}}{\text{Number of post race survey respondents}} \times 100$$

I identified swimmers who had experienced suspected episodes of SIPE from the post-race survey data using my differing SIPE case definitions, from the broadest to narrowest set of criteria.

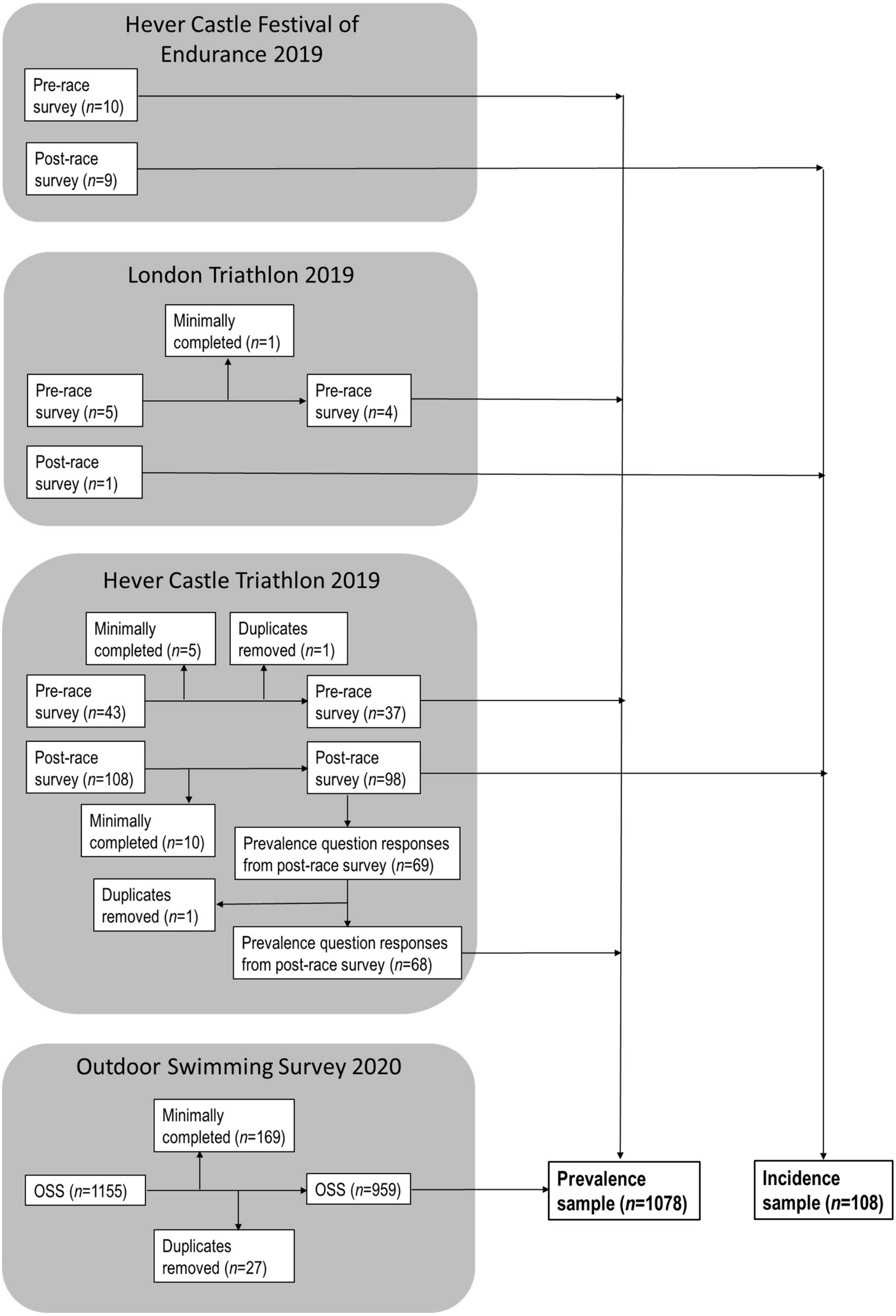

Figure 2: Flowchart showing routes of recruitment to prevalence and incidence samples. OSS = outdoor swimming survey

5.4 Prevalence study results

5.4.1 Participants

5.4.1.1 Methods of recruitment

For the prevalence sample I included responses collected from the three event pre-race surveys (*n*=58) and the outdoor swimming survey (*n*=1,155). In order to boost the sample size I decided to include some prevalence questions in the Hever Castle Triathlon post-race survey, so these responses were also included in the prevalence sample (*n*=69). In total, the three event surveys achieved 127 responses for the prevalence sample. The response rates for Hever Castle Triathlon pre and post-race surveys were 1.5% and 2.4% respectively. It was not possible to calculate a response rate for the London Triathlon survey and outdoor swimming survey because no survey invitations were emailed to competitors and the number who had seen the Facebook posts and/or tweets was unknown. When the 1,155 responses to the outdoor swimming survey were added to the event survey responses, this amounted to 1,282 responses in total. After duplicates and minimally completed responses were removed, this left 1,078 responses for analysis (see Table 17 for detailed breakdown).

Table 17: Prevalence sample responses

			Excluded responses		
Survey	**All responses**	**Response rate (%)**	**Minimally completed[1]**	**Duplicates**	**Included responses**
Hever Castle Festival of Endurance pre-race survey	10	1.5	0	0	10
Hever Castle Triathlon pre-race survey	43	1.5	5	1	37
Hever Castle Triathlon post-race survey[2]	69	2.4	0	1	68
London Triathlon	5	Unknown	1	0	4
Outdoor swimming survey	1,155	Unknown	169	27	959
Total responses	1,282	Unknown	175	29	1,078

[1]where respondent failed to answer the first question; [2]prevalence questions included in this post-race survey

All Hever Castle Festival of Endurance responses that were included in the analysis originated from hyperlinks in the survey invitation emails. For Hever Castle Triathlon, responses came from hyperlinks and the QR code included in the email invite, on the digital flyer, and on posters displayed at the event, as well as in person from competitors who were approached after the finish line. Responses from London Triathlon competitors all came from the hyperlink included in the post added to the event Facebook page (see Table 18).

Table 18: Mode of prevalence sample responses

Event	Hyperlink	QR code	In person	Total included responses
Hever Castle Festival of Endurance	10	N/A	N/A	10
Hever Castle Triathlon (pre-race survey)	35	1	1	37
Hever Castle Triathlon (post-race survey)	49	3	16	68
London Triathlon	4	N/A	N/A	4
Outdoor swimming survey	959	N/A	N/A	959
Total responses	1,057	4	17	1,078

5.4.1.2 Demographics

Table 19 gives the demographics of respondents included in the prevalence sample. This shows the age structure was slightly different between the event surveys and outdoor swimming survey; 65% of outdoor swimming survey respondents were aged between 40 and 59, whereas over 65% of event survey respondents were 30 to 49. There was a fairly even split between males and females in the event surveys, but over two thirds of outdoor swimming survey respondents were female. Ethnicity was predominantly white for both the event surveys and outdoor swimming survey at 98% and 96% respectively. As would be expected for events in the South East region, the majority (79%) of competitors that took part were from London and the South, however, the outdoor swimming survey attracted a much wider geographic distribution of respondents with only half coming from London and the South.

Around 57–59% of respondents said they had never smoked. Over 80% of event survey respondents entered a multi-sport race that involved swimming; predominantly triathlons (77%), but also a small number of aquathlons (swim, run) and aquabike (swim, bike) races. Over 95% of the outdoor swimming survey respondents were regular outdoor swimmers, with only 3% describing themselves as occasional outdoor swimmers. Less than a third of the outdoor swimming survey respondents

Table 19: Demographics of respondents included in prevalence sample

Variable	Event surveys *N* (%)	Outdoor swimming survey *N* (%)	Prevalence sample *N* (%)
Overall	119 (11.0[1])	959 (89.0[1])	1078 (100[1])
Age			
<20	1 (0.8)	1 (0.1)	2 (0.2)
20-29	21 (17.6)	72 (7.5)	93 (8.6)
30-39	40 (33.6)	160 (16.6)	199 (18.5)
40-49	38 (31.9)	331 (34.5)	369 (34.2)
50-59	17 (14.3)	288 (30.0)	305 (28.3)
60-69	2 (1.7)	85 (8.9)	87 (8.1)
≥70	0 (0)	15 (1.6)	15 (1.4)
Data missing	0 (0)	8 (0.8)	8 (0.7)
Sex			
Female	62 (52.1)	678 (70.7)	740 (68.7)
Male	57 (47.9)	268 (28.0)	325 (30.2)
Prefer not to say/other/data missing	0 (0)	13 (1.4)	13 (1.2)
Ethnicity			
White	117 (98.3)	923 (96.3)	1040 (96.5)
Mixed	2 (1.7)	17 (1.8)	19 (1.8)
Black/Black British	0 (0)	1 (0.1)	1 (0.1)
Chinese or other	0 (0)	2 (0.2)	2 (0.2)
Prefer not to say/data missing	0 (0)	16 (1.7)	16 (1.5)
Region of residence			
London & South	94 (79.0)	494 (51.5)	588 (54.6)
Midlands & East	15 (12.6)	129 (13.5)	144 (13.4)
North	3 (2.5)	138 (14.4)	141 (13.1)
Wales	3 (2.5)	46 (4.8)	49 (4.6)
Scotland	1 (0.8)	120 (12.5)	121 (11.2)
Other	3 (2.5)	23 (2.4)	26 (2.4)
Data missing	0 (0)	9 (0.9)	9 (0.8)
Smoking status			
Never smoked	70 (58.8)	542 (56.5)	612 (56.8)
Ex-occasional smoker	28 (23.5)	166 (17.3)	194 (18.0)
Ex-daily smoker	18 (15.1)	197 (20.5)	215 (19.9)
Occasional smoker	2 (1.7)	29 (3.0)	31 (2.9)
Daily smoker	1 (0.8)	20 (2.1)	21 (2.0)
Data missing	0 (0.0)	5 (0.5)	5 (0.5)
Type of race entered[2]			
Multi-sport event	100 (84.0)	N/A	N/A
Triathlon (swim, bike, run)	91 (76.5)	N/A	N/A
Aquathlon (swim, run)	7 (5.9)	N/A	N/A
Aquabike (swim, bike)	2 (1.7)	N/A	N/A
Swim only	19 (16.0)	N/A	N/A
Type of swimmer[3]			
Regular outdoor swimmer	N/A	932 (96.6)	N/A
Excluding triathlons	N/A	646 (67.4)	N/A
Including triathlons	N/A	280 (29.2)	N/A
Occasional outdoor swimmer	N/A	28 (2.9)	N/A
Data missing	N/A	5 (0.5)	N/A
Multisport vs swimming only			
Outdoor swimming only	19 (16.0)	646 (69.8)	665 (61.7)
Multisport competitor	100 (84.0)	280 (30.2)	380 (35.3)
Data missing	0 (0.0)	33 (3.4)	33 (3.1)

[1] expressed as a proportion of all 1078 respondents; [2] event surveys only; [3] question not included in event surveys

said they did triathlons. Overall, 35% of the prevalence sample had taken part in multi-sport races including swimming and 62% were outdoor swimmers or swimming only race competitors.

5.4.2 Details of shortness of breath

Twenty-two percent of the prevalence sample respondents said they had experienced SOB during or after swimming that was out of proportion to the effort being put in (see Table 20). Over half (53%) of these swimmers said the SOB occurred immediately on entering the water, compared to later during the swim (41%) or after they had completed their swim (6%).

Table 20: Details of SOB experienced

Variable	Event surveys *N* (%)	Outdoor swimming survey *N* (%)	Prevalence sample *N* (%)
Total	119 (100)	959 (100)	1,078 (100)
Ever had SOB[1]			
Yes	28 (23.5)	211 (22.1)	239 (22.2)
No	91 (76.5)	748 (78.0)	839 (77.8)
Data missing	0 (0.0)	0 (0.0)	0 (0.0)
When SOB started[2]			
Immediately on entering the water	17 (60.7)	110 (52.1)	127 (53.1)
Later during swim	11 (39.3)	87 (41.2)	98 (41.0)
After swim	0 (0.0)	14 (6.6)	14 (5.9)
Data missing	0 (0.0)	0 (0.0)	0 (0.0)

SOB = shortness of breath; [1]percentages expressed as a proportion of responses to given survey(s); [2]percentages expressed as a proportion of respondents that had experienced SOB

Sixty-two percent of respondents that had experienced SOB during or after swimming that was out of proportion to the effort being put in (*n*=148) attributed their SOB to cold shock response, with an additional 3% (*n*=7) reporting the cold temperature as a main contributing factor. One fifth suspected the SOB was caused by a panic attack, with a further 3% reporting mild panic, anxiety, fear or stress. Other hypothesized reasons included asthma (16%), inhaling water (7%), allergies (6%) and a wetsuit (5%).

Only three respondents (1.3%) said they thought their SOB may have been due to SIPE (see Table 21). They included two females in their forties and fifties respectively, and one male in his forties, all of whom had experienced a similar episode of SOB once before. The females were year round regular outdoor swimmers who had suffered SOB later in their swim. The male was a triathlete who swam outdoors in the warmer months only and who experienced SOB immediately on entering the water. All three reported feeling tightness in their chest during their most recent episode of SOB, with both females experiencing additional symptoms. None of the three swimmers thought they had inhaled water. One of the females was asthmatic while the male had previously experienced asthma-like symptoms. Two of the swimmers suggested they had experienced symptoms of the following conditions in the past; asthma, hay fever and panic attack (male swimmer) and Raynaud's (female swimmer aged 40-49 years old). Both females sought medical attention regarding their SOB and the asthma sufferer was told her breathlessness was likely to be due to asthma.

Table 21: Description of respondents who attributed their SOB to SIPE

Variable	Case 1	Case 2	Case 3
Ageband	40–49	40–49	50–59
Sex	Male	Female	Female
Year of last SOB episode	Last year (2019)	Last year (2019)	4–5 years ago (2015–16)
Age at time of last SOB	40–49	30–39	50–59
Type of swimmer	Triathlete	Outdoor swimmer	Outdoor swimmer
Outdoor swimming months	April to September	All year	All year
When SOB started	Immediately	Later in swim	Later in swim
Other symptoms	Tight chest	Wheeze/whistling, cough, tight chest	Blood tinged phlegm, tight chest and neck
Water aspiration	No	No	No
Total number of SOB episodes	2	2	2
Diagnosed health conditions	Asthma	None	Asthma
Conditions for which symptoms ever experienced	Asthma, hay fever, panic attack	Raynaud's disease	None
HP consulted regarding SOB	No	Yes, no further details provided	Yes, HP thought SOB due to asthma

SOB = shortness of breath; HP = health professional

5.4.3 SIPE case ascertainment responses

Figure 3 shows the responses given for the case ascertainment questions in the survey. It shows that 16 respondents reported an unexplained cough during their last episode of SOB and eight said they were coughing up sputum.

5.4.4 Prevalence estimates

Table 22 shows the prevalence of ever having experienced an episode of SIPE based on a number of different case definitions, from the broadest to narrowest set of criteria. The results show 22% of respondents in the prevalence sample reported having experienced SOB during or straight after swimming that was out of proportion to effort being put in. When those that had inhaled water were excluded the prevalence was reduced to 20%. This fell to 9% if cases that occurred immediately on entering the water were excluded. If the case definition required the presence of a cough, the estimated prevalence fell to 0.6%. If phlegm or specifically pink, red or blood stained phlegm, froth or fluid were required symptoms, the prevalence decreased to 0.4% and 0.1% respectively. No respondents had been formally diagnosed with SIPE.

Table 22: Prevalence of SIPE based on different case definitions (broadest to narrowest criteria)

SIPE case definition	*N*	Prevalence (%)	95% CI
All respondents	1,078	100	
SOB immediately, during or straight after swimming	239	22.2	19.7–24.8
SOB immediately, during or straight after swimming, in absence of water aspiration	216	20.0	17.7–22.6
SOB not immediately in absence of water aspiration	97	9.0	7.4–10.9
SOB and cough not immediately in absence of water aspiration	7	0.6	0.3–1.3
SOB and coughing up sputum not immediately in absence of water aspiration	4	0.4	0.1–0.9
SOB and coughing up pink, red or blood sputum not immediately in absence of water aspiration	1	0.1	0.002–0.52
SOB during or after swim and evidence of pulmonary oedema on examination	0	0	0

SOB = shortness of breath

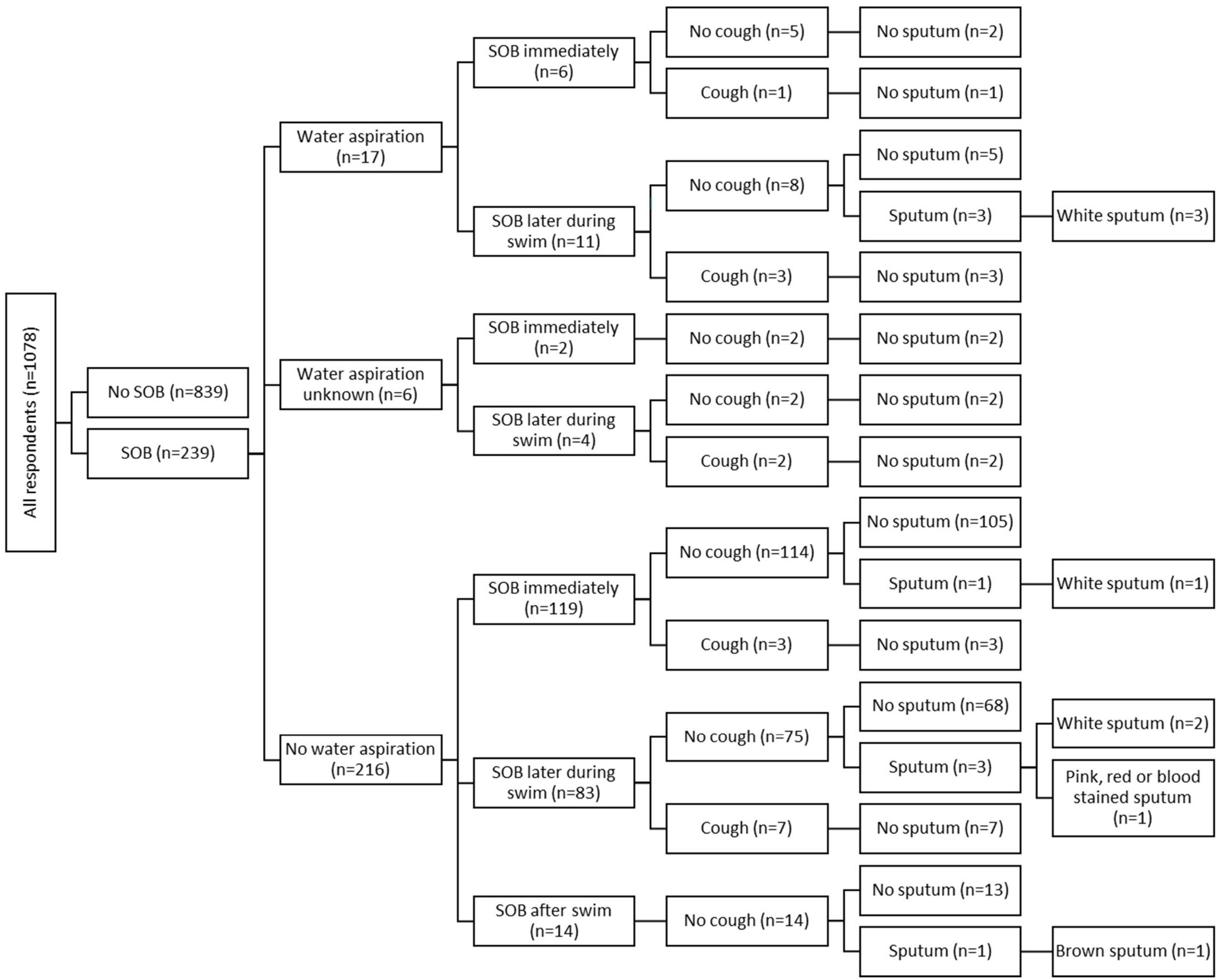

Figure 3: Flowchart of responses to case definition questionnaire items in prevalence sample. SOB = shortness of breath

5.5 Incidence study results

5.5.1 Participants

5.5.1.1 Methods of recruitment

For the incidence sample, I included data collected from the three event post-race surveys. In total, 118 responses were received. Ten minimally completed responses were excluded which left 108 responses for inclusion in the incidence sample (see Table 23 for detailed breakdown). Over a quarter of post-race survey respondents (*n*=32) had also completed the pre-race survey for their respective events; 24 for Hever Castle Triathlon, seven for Hever Castle Festival of Endurance and one for London Triathlon.

Table 23: Incidence sample responses

			Excluded responses		
Post-race survey	**All responses**	**Response rate (%)**	**Minimally completed**	**Duplicates**	**Included responses**
Hever Castle Festival of Endurance	9	1.4	0	0	9
Hever Castle Triathlon	108	3.7	10	0	98
London Triathlon	1	Unknown	0	0	1
Total responses	118	Unknown	10	0	108

All responses to Hever Festival of Endurance and London Triathlon post-race surveys came from hyperlinks on the email survey invitation. Hever Castle Triathlon responses originated from a mixture of email hyperlinks, the QR code on the online flyer and posters displayed at the event, and in-person responses at the event (see Table 24).

Table 24: Sources of incidence sample responses

Post-race survey	**Hyperlink**	**QR code**	**In person**	**Total included responses**
Hever Castle Festival of Endurance	9	N/A	N/A	9
London Triathlon	1	N/A	N/A	1
Hever Castle Triathlon	77	3	18	98
Total responses	87	3	18	108

5.5.1.2 Demographics

Respondent demographics are shown in Table 25. Over 60% of respondents were aged between 30 and 49 with most of the remainder fairly equally split between 20–29 and 50–59 year olds. There was a slightly higher proportion of female respondents than males. Ethnicity was 93% white and almost three quarters of respondents were from London and the south of England. The majority of respondents (83%) took part in a multi-sport event. Nearly 60% of respondents said they had never smoked.

5.5.2 Details of shortness of breath

Sixteen out of 108 respondents experienced SOB during or after swimming that was out of proportion to the effort being put in (see Table 26). Most of these episodes of SOB occurred immediately on entering the water (*n*=9) or later during the swim (*n*=6).

None of the 16 respondents in the incidence sample that reported SOB thought they had experienced SIPE. Eleven attributed the SOB episode to cold shock (although two said their SOB began later in their swim so may have misunderstood the question or when cold shock occurs) and four thought they may have inhaled water. Panic attack, asthma, allergies and a heart condition were also suggested as possible causes. None of the respondents reported being seen by a health professional.

Table 25: Demographics of respondents included in incidence sample

Variable	**Incidence sample** *N* **(%)**
Overall	108 (100)
Age	
<20	1 (0.9)
20 - 29	17 (15.7)
30 - 39	34 (31.5)
40 - 49	32 (29.6)
50 - 59	16 (14.8)
≥60	0 (0.0)
Data missing	6 (5.6)
Sex	
Male	48 (44.4)
Female	54 (50.0)
Data missing	6 (5.6)
Ethnicity	
White	100 (92.6)
Mixed	2 (1.9)
Data missing	6 (5.6)
Region of residence	
London & South	78 (72.2)
Midlands & East	15 (13.9)
North	3 (2.8)
Wales	2 (1.9)
Scotland	1 (0.9)
Other	3 (2.8)
Data missing	6 (5.6)
Smoking status	
Never smoked	63 (58.3)
Ex-smoker	38 (35.2)
Current smoker	1 (35.2)
Data missing	6 (5.6)
Type of race entered	
Multi-sport event	90 (83.3)
Triathlon (swim, bike, run)	80 (74.1)
Aquathlon (swim, run)	7 (6.5)
Aquabike (swim, bike)	3 (2.8)
Swim only	18 (16.7)

Table 26: Details of shortness of breath experienced

Variable	**Incidence sample** *N* **(%)**
SOB reported[1]	
Yes	16 (14.8)
No	92 (85.2)
When SOB started[2]	
Immediately	9 (56.3)
Later during swim	6 (37.5)
After swim	1 (6.3)
Data missing	0 (0.0)

SOB = shortness of breath; [1] percentages expressed as a proportion of responses to event surveys; [2]percentages expressed as a proportion of respondents that reported SOB

5.5.3 SIPE case ascertainment responses

Figure 4 indicates the responses given for each of the case ascertainment questions in the post-race survey. It shows none of the respondents reported an unexplained cough, or coughing up sputum during their race.

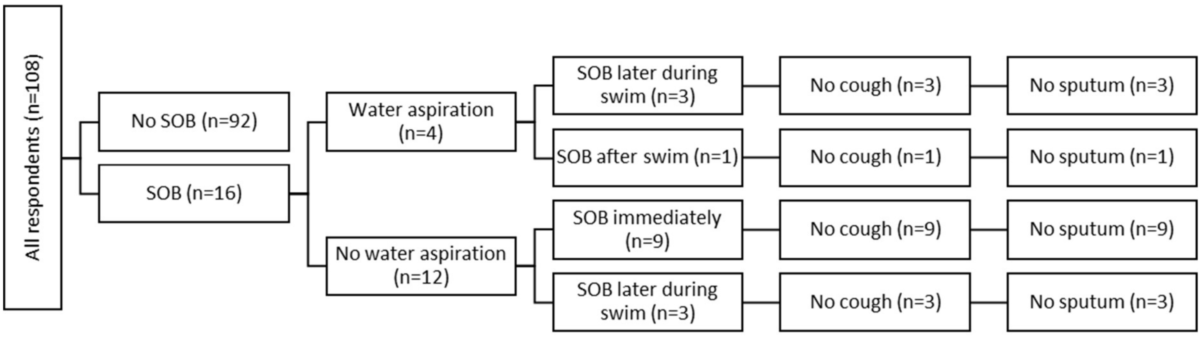

Figure 4: Flowchart of responses to case definition questionnaire items in incidence sample. SOB = shortness of breath

5.5.4 Incidence estimates

Estimates of incidence based on differing case definitions from broadest to narrowest are shown in Table 27. Based on the case definition of SOB immediately, during or straight after their swimming race that was out of proportion to effort they were putting in, 16 respondents met the criteria, giving an incidence estimate of 15% of competitors per swimming race. This number is reduced to four respondents (4%) when water aspiration is excluded. If those whose SOB occurred immediately on entering the water are excluded, incidence becomes 3% of competitors per swimming race. None of the respondents thought they had experienced SIPE or saw a health professional who attributed their SOB to SIPE.

Table 27: Incidence of SIPE based on different case definitions (broadest to narrowest criteria)

SIPE case definition	*N*	Incidence per swimming race (%)	95% CI
All respondents	108	100	
SOB immediately, during or after swim	16	14.8	8.7–22.9
SOB immediately, during or after swim in absence of water aspiration	4	3.7	1.0–9.2
SOB not immediately in absence of water aspiration	3	2.8	0.6–7.9
SOB and cough not immediately in absence of water aspiration	0	0	N/A
SOB and coughing up sputum not immediately in absence of water aspiration	0	0	N/A
SOB and coughing up pink, red or blood stained sputum not immediately in absence of water aspiration	0	0	N/A
SOB during or after swim and evidence of pulmonary oedema on examination	0	0	N/A

SOB = shortness of breath

5.6 Discussion

5.6.1 Findings

In my analysis I found the prevalence of ever having SIPE was between 0.1%, 95% CI (0.002 to 0.5) and 22.2%, 95% CI (19.7 to 24.8), depending on the case definition used. Incidence of SIPE, which was a much less robust finding, was between 2.8%, 95% CI (0.6 to 7.9) and 14.8%, 95% CI (8.7 to 22.9) of competitors per swimming race. Three participants in the prevalence study thought they may have experienced SIPE, however, none had this diagnosed by a health professional. It was not possible to calculate overall response rates, but for the Hever Castle surveys this was approximately 3.4% for the prevalence study and 3.3% for the incidence study.

5.6.2 Limitations

There are a number of limitations to the studies. Firstly, the precision of prevalence and incidence estimates was limited by sample size. Sample size for the prevalence study was reasonably large at 1,078 respondents, however, the incidence study sample was very small at 108 due to participants being restricted to competitors at selected triathlon events. This led to incidence estimates with poorer precision as indicated by the very wide 95% confidence intervals. This makes it is difficult to generalise these results, meaning they are of limited value. My prevalence estimates on the other hand were much more precise, with the achieved sample size close to my target, and 95% confidence intervals of reasonable width.

As discussed in section 5.1, defining the population of interest was difficult due to the absence of a register of outdoor swimmers in the UK. Therefore, for the prevalence study I targeted competitors at selected triathlon events and later extended to all outdoor swimmers in the UK to increase sample size. The resulting sample was very heterogeneous, made up of 35% multi-sport race competitors, 65% outdoor swimmers/swimming only race competitors. The participants ranged from infrequent recreational swimmers to seriously competitive endurance athletes, which will have incorporated a huge spectrum of swimming behaviours. The incidence sample was a much less diverse group, 83% of whom had entered a multi-sport race (predominantly triathlons), with just 16% taking part in swimming only races. However, it still varied greatly from first time outdoor swimmers to national level competitive triathletes. The heterogeneity of the samples makes it difficult to generalise the results, as it is not certain what type of swimmer these estimates can be applied to and therefore what the implications of the studies are to an individual.

Response bias whereby previous SIPE sufferers were more likely to take part was identified as a potential risk in both the prevalence and incidence studies. This could have led to inflated estimates, therefore, to try to minimise this risk I named the surveys “outdoor swimming surveys” and described them in generic terms as health surveys for outdoor swimmers. The very low response rates of 3.4% and 3.3% suggest there may be been an increased risk of nonresponse bias, if nonresponse was unequally distributed among those invited to take part.

Both studies were limited by the difficulty in including people that had given up open water swimming due to SIPE. This was the case for some of the questionnaire testing participants who had experienced SIPE and been advised to discontinue cold water swimming by their doctor. This may have caused response bias because these people were no longer in the target population group of the survey, which could have led to underestimates of prevalence and incidence.

Double counting of survey respondents could have been an issue. Although I collected respondent email address to identify and exclude duplicate responses (27 duplicates were found in the outdoor swimming survey), I may not have detected respondents who provided more than one email address.

The incidence study had the additional risk of participants being lost to follow-up, which could have caused bias and threatened the validity of the study. However, the follow-up time between pre and post-race surveys was a short period of a few weeks, therefore this would have been less of a risk. The results showed that 30% of pre-race survey participants went on to complete the post-race survey. Despite the limitations, the study and subsequent analysis is very detailed and produces some very useful findings.

5.6.3 Comparison with other literature

My study estimated SIPE prevalence to be between 0.1% and 22.2%, depending on the case definition used. The broadest case definition was *"SOB immediately, during or after swimming"*. This is a very generic set of symptoms that could include SOB due to cold shock response, something which commonly occurs immediately on entering cold water, as well as SOB due to having aspirated water. When I narrowed the case definition to exclude both of these factors i.e. *"shortness of breath not immediately in absence of water aspiration"*, it resulted in a prevalence estimate of 9% and when I included the presence of a cough, prevalence was reduced to 0.6%. My lowest prevalence estimate of 0.1% was based on the strictest case definition, which required the swimmer to have coughed up pink, red or blood stained sputum not immediately, in the absence of water aspiration. This is the closest case definition to the one used by Miller, Calder-Becker and Modave (2010) who reported a lifetime prevalence of SIPE of 1.4% based on those who said they had *"a cough productive of pink frothy or blood-tinged secretions during swimming"*. The reason for this higher estimate may have been because their sample was made up of competitive triathletes, so excluded non-triathlete open water swimmers who made up 62% of my prevalence sample.

My incidence estimates ranged from 2.8% to 14.8% of outdoor swimming race competitors, depending on the case definition used. Similar to the prevalence study, the broadest case definition was *"SOB immediately, during or after swimming"*, which could have included cases of cold shock response and swimmers who had aspirated water. A slightly stricter case definition, which excluded immediate SOB and water aspiration, resulted in an estimated incidence of 2.8%. This is still a much broader case definition than those used in eight published incidence studies, most of which also required a cough and/or sputum (Smith *et al.* 2017; Adir *et al.* 2004; Shupak *et al.* 2000; Weiler-Ravell *et al.* 1995; Sebreros *et al.* 2023; Volk *et al.* 2021), and/or clinical examination (Adir *et al.* 2004; Smith *et al.* 2017; Weiler-Ravell *et al.* 1995; Kristiansson *et al.* 2023; Sebreros *et al.* 2023; Lindqvist *et al.* 2022; Hårdstedt *et al.* 2021; Volk *et al.* 2021). These published studies reported SIPE incidence as 1.8%, 16.6% and 26.7% of time trials performed by Israeli military trainees (Weiler-Ravell *et al.*, 1995; Shupak *et al.*, 2000; Adir *et al.*, 2004 respectively), 4.3% and 5.0% of Navy SEAL candidates (Volk *et al.*, 2021; Sebreros *et al.*, 2023 respectively), 0.01% of triathlons raced in the UK (Smith *et al.* 2017), 0.44% of outdoor swimming races started at the Swedish event (Hårdstedt *et al.* 2021), and 25.0% of the trained long-distance open water swimmers that took part in an eight hour swim (Lindqvist *et al.* 2022). The wide range of incidence estimates is likely to be due to the high heterogeneity of the studies, which differed in swimming environment, population characteristics and denominators, and SIPE case definition.

5.6.4 What it all means

There were a number of things to consider when selecting my working case definition for SIPE. It needed to be able to be used in the absence of a medical professional, and I wanted it to include milder as well as more severe cases of SIPE. Therefore, I excluded the requirement for clinical examination and the presence of a cough and sputum, and designated the following as my working case definition:

An attack of SOB that was reported by the swimmer as being out of proportion to the effort being put in, and EITHER:

(a) a doctor has told them that it was due to pulmonary oedema or SIPE, OR

(b) they do not believe it was caused by inhaling water AND it did not occur immediately on entering the water

The resulting lifetime prevalence estimate was 9%, 95% CI (7.4% to 10.9%) of outdoor swimmers, with an incidence estimate of 2.8%, 95% CI (0.6% to 7.9%) of competitors per outdoor swimming race, both of which I believe to be reasonably good estimates.

The Active Lives Survey 2022/2023 estimated that around 4.4 million people in England had taken part in open water swimming in the past year (Sport England, 2024). If I apply the SIPE prevalence estimate of 9% to these figures, it equates to almost 400,000 open water swimmers who may have previously experienced SIPE. This suggests SIPE may be a significant problem in the UK, so awareness and an understanding of the condition is important amongst swimming venues, event organisers, health professionals and outdoor swimmers themselves.

A SIPE incidence of 2.8% of outdoor swimming race participants suggests we might expect around 28 cases of mild to severe SIPE during a large triathlon race with 1,000 competitors. This estimate is subject to a large degree of uncertainty due to the limited precision of the incidence estimate, however, some cases may potentially need assistance whilst in the water, or medical treatment after their swim. This therefore has important implications for event organisers, marshals and competitors.

These findings are important because there is currently no standard case definition of SIPE and my results provide fairly robust estimates of prevalence based on an array of case definitions, from a very broad to very narrow set of symptoms.

5.7 Conclusions

The results of my prevalence and incidence studies suggest that SIPE is a significant problem among outdoor swimmers and previous estimates may not reflect the true burden of the condition. More studies are needed that can identify swimmers who experience milder symptoms of SIPE, as well as those who require medical help, to better understand the scale of the problem. This knowledge will help inform policy and guidance so adequate measures can be taken by all stakeholders to improve safety and ensure those affected are able to receive medical care if necessary.

Chapter 6: Risk factors for SIPE

6.1 Introduction

The purpose of this chapter is to report a study into risk factors for SIPE. This is important as it will improve the understanding of factors that increase the likelihood of SIPE occurring and will help to identify the cause so that preventative interventions can be implemented. It will also inform open water swimming event organisers and individual swimmers to improve safety in outdoor swimming.

There is limited evidence on the risk factors for SIPE. My systematic review found only five studies that made a contribution to our understanding of the risk factors. The studies included a case-control study of triathletes in the US (Miller, Calder-Becker and Modave 2010), two cohort studies of military trainees (Shupak *et al.* 2000; Sebreros *et al.* 2023), a study of competitors of an annual Swedish open water swimming event (Hårdstedt *et al.* 2021), and a small clinical trial of ten swimmers who had experienced SIPE (Moon, Martina, Peacher, Potter, *et al.* 2016). The studies lacked in statistical power due to small sample sizes and were also limited in design (see chapter 3 for further details).

While the evidence remains weak at best, the strongest evidence suggests that hypertension, female sex, age over 30, taking fish oil supplements and long course distance may be risk factors. Additional possible risk factors that may or may not be on the causal pathway included higher mean pulmonary artery pressures, lower lung volumes and flows, and lower tidal volumes during exercise in cold water. However, further research is needed to replicate findings on these risk factors and to explore additional hypothesized risk factors. This risk factors study takes forward these recommendations through an investigation into a group of suspected risk factors for SIPE. This work includes an evaluation of evidence for causality using the Bradford Hill criteria.

Figure 5 below shows the conceptual framework for the risk factors I explored, categorising them into modifiable, non-modifiable and comorbidities. Some of these risk factors may be on the causal path, some may be confounders and some may be effect modifiers.

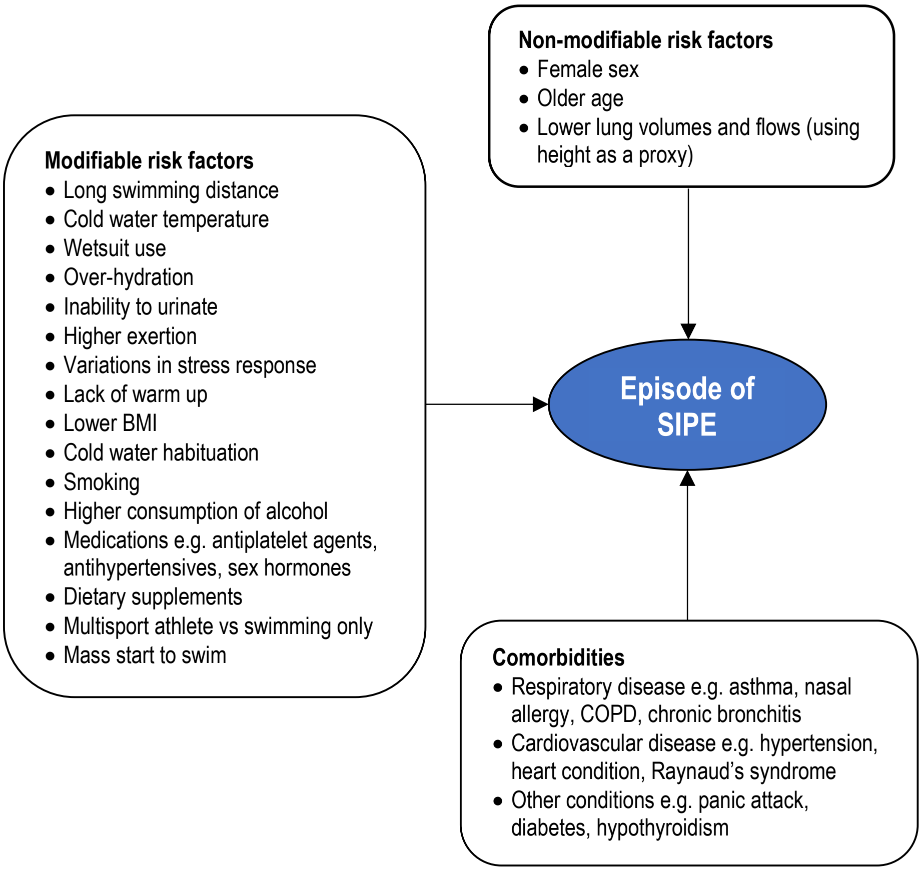

Figure 5: Risk factors investigated. (Note: Multisport athletes are swimmers that reported taking part in a triathlon or multisport race involving cycling or running in addition to swimming.)

6.2 Methods

6.2.1 Study design

I carried out an unmatched case-control study of outdoor swimmers in the UK. Swimmers who reported having ever experienced an episode of SOB that could have been caused by SIPE were compared to those that had never experienced any SOB related to outdoor swimming.

I considered controlling for the effect of confounders such as age and sex at the design stage. One option was to restrict the sample to specific age criteria or to just one sex. This might have made it more difficult and time consuming to recruit the required number of participants and would have made the study less generalizable to the whole target population of outdoor swimmers. Another option was to carry out a matched case control study, matching by age group and sex, for example. I chose not to use matching due the following disadvantages:

1. Reduced sample size

The process of matching typically involves pairing a case with one or more controls whose matched variables are similar. This may result in cases being excluded if an appropriate control cannot be found, or vice versa. Not only does this result in the loss of valuable data and therefore precision, but it also creates selection bias and means the sample will be less generalizable to the broader target population.

2. Loss of information

If matching is done using categories that are too broad, information may be lost, meaning the matching variable may not be adequately adjusted for. This may lead to residual confounding.

3. Selection bias

The process of matching cases to controls causes selection bias. This is because the selection of cases and controls is not random but based on knowledge of the exposure or outcome.

4. Overmatching

This can occur if a matched variable is not a true confounder, or if the degree of matching is excessive. A variable is not a true confounder if it is not associated with the outcome in the absence of the exposure, or if it is a mediator on the causal pathway. Excessive matching occurs when too many matched variables are used or matching criteria are too strict. In these situations the cases and controls end up being so similar that it is difficult to investigate the true relationship between the exposure and the outcome. This leads to biased results.

5. Reduced precision

If matched variables are not strong enough confounders, the precision with which the association between the exposure and outcome can be measured may be reduced. Matching also involves creating groups of participants with similar characteristics, which reduces the variability within the groups. This makes it more difficult to detect significant differences between cases and controls, thus reducing the precision of the exposure-disease relationship.

6. Sparse data

Matching may lead to very few cases in each matched set, which requires the use of sparse-data methods of analysis. Even these methods can suffer from sparse-data bias when there are not enough discordant pairs i.e. where the case and control have different exposures, or when the model contains too many variables.

7. Limits exploration of matched variables

It would not be possible to study the confounding variables that form the matching criteria. For example, if I had matched cases and controls by age and sex, I would not have been able to study the relationship between these two variables and SIPE, since comparing the age/sex makeup of cases and controls would only show how well cases and controls had been matched.

Therefore, instead of adjusting for confounders at the design stage, I chose to control for their effect at the analysis stage through the inclusion of age and sex variables in multivariate regression models (see section 6.2.9 on statistical methods).

6.2.2 Sample

I used the data collected during from the prevalence and incidence studies (described in chapter 5), plus those collected during the questionnaire testing phase (described in chapter 4). The sample included adult competitors of three large triathlon events in 2019 (Hever Castle Festival of Endurance, Hever Castle Triathlon, and London Triathlon), respondents to the outdoor swimmer survey conducted in February–April 2020, and swimmers that took part in questionnaire testing in March–May 2019.

Recruitment of respondents from Hever Castle events was done with the help of the event organiser who included survey invitations in their pre and post-race emails to competitors. I also used Facebook and Twitter to publicise the Hever Castle Triathlon and London Triathlon surveys. Some responses to Hever Castle Triathlon post-race survey were collected at the event itself, either in person or through promotional posters. For the outdoor swimmer survey, I recruited participants mainly through social media i.e. Facebook and Twitter. The Winter/Spring 2020 issue of the University of Kent CHSS newsletter also included a survey invitation. As an incentive, all participants who completed the event surveys or outdoor swimming survey were offered the chance to win a £100 Wiggle voucher in a prize draw.

In addition to the responses collected by the above surveys, the risk factor sample included responses of volunteers who had taken part in the testing phase of an early version of the online questionnaire. These participants were recruited through local triathlon and outdoor swimming clubs, and through personal contacts. Online Wiggle vouchers worth £5 were offered as incentives for taking part.

Ethical approval for conducting the surveys was obtained from the University of Kent's SSPSSR SRC Ethics Committee (SRCEA id 237).

6.2.3 Participants

Eligibility criteria for the event surveys included adults (aged ≥18) who were registered to take part in races that involved outdoor swimming. Outdoor swimming survey participants were recreational outdoor swimmers in the UK. As a result, study participants were a heterogeneous group, ranging from less frequent recreational swimmers to marathon swimmers and competitive endurance triathletes.

As discussed in chapter 4, there is no currently universal accepted epidemiological case definition or diagnostic criteria for SIPE. I used the following SIPE case definition to identify people who had experienced SIPE or symptoms suggestive of SIPE:

An attack of SOB that was reported by the swimmer as being out of proportion to the effort being put in, and EITHER:

(a) A doctor has told them that it was due to pulmonary oedema or SIPE; OR

(b) They do not believe it was caused by inhaling water AND it did not occur immediately on entering the water

This case definition was applied slightly differently depending on which survey had been completed. For post-race survey respondents, the SOB had to have happened during the respondent's swimming race, whereas for outdoor swimming survey respondents, pre-race survey respondents (including those that completed pre-race survey questions contained in the post-race survey), and those that took part in questionnaire testing, the SOB could have occurred at any point in their lifetime.

Once cases of SIPE had been identified from the sample, respondents who had not experienced any SOB (either during their swimming race for post-race survey respondents, or *ever* for the remaining respondents), were assigned to the control group. Although the additional power that can be achieved by ratios of controls to cases of over 4:1 is limited (Raina 2016), I followed guidance from Boston University School of Public Health that suggested there was little reason to restrict the number of controls if data are easily obtained (LaMorte 2016). The remaining respondents who had experienced SOB but did not meet the case definition, were excluded from the analysis i.e. where SOB occurred immediately on entering the water or they believed it may have been caused by inhaling water and they were not told by a doctor the SOB was due to SIPE.

6.2.4 Variables

The outcome variable of interest was symptoms of SOB that met the case definition detailed above. Predictor variables were categorised as modifiable and non-modifiable risk factors, as well as comorbidities. Non-modifiable risk factor variables included the following:

- Sex
- Age
- Height (used for BMI calculations and as a proxy for lung volumes/flows)

Modifiable risk factor variables were:

- Water temperature
- Wetsuit use including type i.e. shorty/full length, sleeve length and whether tight fitting
- Swimming distance
- Pre-swim drinks consumed including volume and type
- Maximum exertion level
- Anxiety/nervousness during swimming
- Body weight (for BMI calculations)
- BMI
- Regular medications/supplements
- Smoking habits
- Alcohol consumption volumes and frequency
- Outdoor swimming frequency (used as a proxy for the extent of previous exposure to cold water and level of cold water habituation)
- Months in which respondent had swum outdoors in the UK (another proxy for extent of exposure to cold water and level of cold water habituation)
- Type of swimmer i.e. multisport swimmer versus swimming only

Comorbidity variables included the following:

- Respiratory diseases e.g. asthma, COPD, chronic bronchitis, nasal allergies
- Cardiovascular diseases e.g. hypertension, cardiac dysfunction, Raynaud's syndrome
- Other medical conditions e.g. diabetes, panic attack disorder, hypothyroidism

These hypothesized risk factors included variables that may be on the causal pathway as well as confounders, effect modifiers and mediators. Height data were analysed separately for males and females due to their bimodal distribution. Other independent variables that were likely to be highly collinear included certain health conditions with age, sex or medications used for their treatment. If included in the same predictive model, this collinearity violates one of the assumptions of logistic regression modelling, making it difficult to separate the effects of each of the variables. As a result the variances of model coefficients become very large with highly unstable effect estimates (Rothman, Greenland and Lash 2011). It was therefore important to mitigate for these effects in multivariate analyses by excluding collinear variables from the model or combining them into a single variable.

6.2.5 Data sources/measurement

All data were collected using the online questionnaires described in Chapter 4 and included in Appendices 8, 9, 13, 14 and 15. For each variable, I will give details of questions used to gather information.

6.2.5.1 Outcome variable

For the outdoor swimming survey, pre-race survey questions and pre-race questionnaire testing, respondents were asked if they had ever had SOB during or straight after swimming outdoors that was out of proportion to the effort they were putting in. The question included in post-race surveys was slightly different; it asked if the respondent had experienced this type of SOB during or straight after their swim at the event. For post-race questionnaire tests, known SIPE cases were asked about the last outdoor swim when they had SIPE, while others were asked about their most recent outdoor swim. If a respondent completed both the pre and post-race surveys and therefore both of these questions, the analysis was carried out using just the post-race survey response to this question. This was because the post-race survey contained questions on possible triggers, defined as time dependent factors that only existed for duration of the race, so needed to be associated with any SOB that occurred during the race, whereas the long-term risk factors that were identified in the pre-race survey would still be valid for the period of the race.

Those that answered yes to one of the above questions were given two follow-up questions referring to either the last time they experienced this type of SOB (in the case of outdoor swimming survey, pre-race survey questions and questionnaire testing respondents), or the SOB that happened at the event (in the case of post-race survey respondents). Firstly, they were asked if they thought the SOB was caused by inhaling/breathing in water, and secondly about when the SOB started; immediately, later during the swim or after the swim. Questionnaire testing respondents were asked a slightly different version of this question; did the SOB occur immediately on entering the water? Respondents who answered *no* or *don't know* to having inhaled/breathed in water and who did not say the SOB started immediately, were deemed to have met the SIPE case definition, so were classed as SIPE cases. Alternatively, respondents that said they had seen a medical professional who thought their SOB was due to SIPE, were also classed as SIPE cases.

6.2.5.2 Unmodifiable risk factor variables

Questions on suspected unmodifiable risk factors for SIPE were included in the outdoor swimming survey, pre-race survey questions (including those contained in the post-race questionnaire) and items used for pre-race questionnaire testing. These variables are discussed below. See section 4.2.2.1 for a discussion of the evidence base for each of the risk factor variables.

Sex

It was important to collect information on respondent sex to be able to control for its effects as a potential confounder. For pre-race survey questions and pre-race questionnaire testing, respondents were asked to select their gender as either male or female in line with race entry categories. For the outdoor swimming survey, respondents were given the additional options of "other" or "prefer not to say". The collected data were used to create a dummy variable for female sex.

Age

The pre-race questionnaire and outdoor swimming survey asked respondents to select their current age from the following age categories: under 20, 20–29, 30–39, 40–49, 50–59, 60–69 and ≥70. I created a new dichotomous age variable for <40 vs ≥40 to use in age adjusted regression analyses to ensure there were enough numbers in each cell of the OR table. Forty was chosen as the cut-off age due to the findings of Miller, Calder-Becker and Modave (2010).

Height

In the pre-race questionnaires and outdoor swimming survey, respondents were asked to specify their height in metres, or feet and inches. These data were then processed in the way described in section 6.2.9 below. Height data were collected for two reasons:

1. As a proxy for lung volumes, given the strong positive correlation between standing height and lung volumes (Wanger et al. 2005). Lower lung volumes (Shupak et al., 2000; Moon, Martina, Peacher, Potter, et al., 2016), lower lung density and mass, and fewer pulmonary lymphatics (Carter et al., 2014) are hypothesized to increase the risk of pulmonary oedema.
2. For BMI calculations (see section 6.2.8 below).

6.2.5.3 Modifiable risk factors

Water temperature

I asked event competitors to estimate the temperature of the water in degrees Celsius during their swimming race. Outdoor swimming survey respondents and post-race questionnaire test respondents were asked for the water temperature during their last outdoor swim (controls) or the last time they experienced SIPE (cases). Section 6.2.8 below describes how these data were processed.

Wetsuit use

The post-race surveys collected information on whether respondents wore a wetsuit during their swimming race. The outdoor swimming survey and post-race questionnaire tests asked if respondents wore a wetsuit the last time they swam outdoors (controls) or the last time they experienced SIPE (cases). Post-race survey and outdoor swimming survey respondents who said *yes* were asked three further questions:

What kind of wetsuit was it?

- *Full length*
- *Shorty*

What kind of sleeves did the wetsuit have?

- *Long sleeves*
- *Short sleeves*
- *Sleeveless*

Did the wetsuit feel very tight or restrictive?

- *Yes*
- *No*

Swimming distance

For event participants, swimming distance was derived from their response to a pre-race survey question asking them to select from a list the race they entered. Outdoor swimming survey and post-race questionnaire test respondents were asked the following:

How far did you swim the last time you swam outdoors in the UK?

- *<500m*
- *500 to 1000m*
- *1001 to 2000m*
- *2001 to 3000m*
- *>3000m*

Data collected from event participants were then allocated to the above distance categories and a new swim distance variable created for all respondents.

Pre-swim drinks consumed

In the post-race survey, I asked event competitors if they had had anything to drink in the hour prior to swimming in their race. Outdoor swimming survey respondents were asked the same question, but referring to either their last outdoor swim (controls) or the last time they had SIPE (cases). For those that answered *yes*, there were two follow-up questions about the type and volume of drink consumed:

> *What did you drink?*
>
> - *Water*
> - *Sports drink*
> - *Tea/coffee*
> - *Other: Please specify*
>
> *In total, how much did you drink in the hour before swimming, based on a regular bike size (500-750 ml capacity) bottle?*
>
> - *Less than half a bottle*
> - *Half to one bottle*
> - *Greater than one bottle*

Post-race questionnaire testing participants were only asked the latter question about the volume of drink consumed. Therefore, it was not possible to differentiate between questionnaire testing respondents who had not had a drink before swimming and those who had consumed less than half a bottle of fluid.

Exertion

In the post-race survey, event competitors were asked to rate the maximum level of effort they put into their swimming race, ranging from 0% (no effort at all) to 100% (maximum effort). Response categories started at 0–9% and increased in intervals of 10 up to 90–100%. I asked for the same information from outdoor swimming survey and post-race questionnaire testing respondents, referring to their last outdoor swim (controls) or the last time they had SIPE (cases).

High levels of anxiety/stress

I asked post-race survey respondents if they felt very nervous or anxious at any time during their swimming race, with response categories of yes or no. Those that answered *yes* were asked to give further details as a free text response. Outdoor swimming survey respondents and post-race questionnaire testing respondents were asked the same question about their last outdoor swim (controls) or their most recent episode of SIPE (cases).

Body weight

The pre-race questionnaires and outdoor swimming survey asked respondents for their weight in kilograms, stones or pounds. Section 6.2.8 describes how these data were treated. These cleaned weight data were used for BMI calculations.

BMI

I calculated BMI using cleaned height and body weight, and processed these data as described in section 6.2.8 below.

Regular medications/supplements

The pre-race questionnaire and outdoor swimming surveys asked if on most days over the last three months, respondents had taken any regular medication or nutritional supplements. Those who answered *yes* were asked to specify which medications and/or supplements using free text. These responses were categorised and the following, dummy variables created:

- Drugs with antiplatelet activity such as the NSAIDs aspirin and clopidogrel
- Supplements with antiplatelet activity such as omega 3 (including fish oil and vegetarian versions), turmeric and vitamin C
- Antihypertensive drugs
- Female sex hormones

Smoking habits

I included the following question in the pre-race survey, outdoor swimming survey and pre-race questionnaire tests:

Which one of these best describes you?

- *I have never smoked*
- *I used to smoke occasionally but do not smoke at all now*
- *I used to smoke daily but do not smoke at all now*
- *I smoke occasionally but not every day*
- *I smoke daily*

Those that selected the second or third options, which suggested they were ex-smokers, were then asked to specify how long ago they quit in a free text response. Two dummy variables were created; smoking status (never smoked/ex-smoker/current smoker) and never smoked versus ever smoked.

Alcohol consumption habits

The pre-race questionnaires and outdoor swimming survey asked the following question:

How often have you had an alcoholic drink of any kind during the last 6 months?

- *Never*
- *Monthly or less*
- *Two to four times per month*
- *Two to three times per week*
- *Four or more times per week*

Respondents who said they had drunk alcohol were then asked about the amount of alcohol consumed:

During the last 6 months, how many alcoholic drinks did you have on a typical day when you drank alcohol?

- *1 to 2*
- *to 4*
- *to 6*
- *to 9*
- *10 or more*

Swimming frequency

Pre-race survey, outdoor swimming survey and questionnaire testing respondents were asked the following question as an indicator of amount of previous exposure to cold water, and the likelihood of them having undergone cold water habituation.

> *How many times have you been outdoor swimming in the UK in the last 12 months? (Include training swims in your answer).*
>
> - *0*
> - *1 to 4*
> - *5 to 9*
> - *10 to 19*
> - *20 or more*

Months of year respondent had swum outdoors

I asked pre-race survey, outdoor swimming survey and questionnaire testing respondents to select from a list the months of the year they had participated in outdoor swimming in the UK. From these data I created a dummy variable to show which respondents said they had swum outdoors in the colder months of the year, and which had only swum during the warmer months. Colder months were defined as January to April based on mean sea temperature data for the UK (SeaTemperature.org 2023). Those that selected the colder months of the year were judged to have had greater exposure to colder water and more likely to be cold acclimatized than those that swam only during the warmer months of May to December.

Multisport athlete vs swimming only

For event survey participants, this variable was created from the information provided in an earlier question about the race they had entered. All races fell into the following categories: swimming only, triathlon, aquathlon (swimming and running) or aquabike (swimming and cycling). Outdoor swimming survey respondents were asked the following question:

> *Which phrase best describes your participation in open water swimming?*
>
> - *I only go open water swimming occasionally or on holiday*

- *I am a regular open water swimmer and do not take part in triathlons*
- *I am a regular open water swimmer and take part in triathlons*

Questionnaire testing respondents were not asked a question about what type of swimmer they were, however, I was able to derive this information from personal contact with them in the course of data collection. I used all the above information to construct a categorical variable for type of swimmer. Event respondents who took part a triathlon, aquathlon or aquabike races, and outdoor swimming survey respondents who said they had taken part in triathlons were deemed to be multisport swimmers. The remaining respondents were categorised as swimming only.

6.2.5.4 Comorbidities

Pre-race questionnaire and outdoor swimming survey respondents were asked if they had ever had symptoms of asthma, allergies such as hay fever, Raynaud's disease or panic attack. Those that said *yes* were then asked if this condition had been confirmed by a health professional. A later question asked if the respondent had ever been diagnosed with any of the following by a health professional: asthma, chronic bronchitis, COPD, emphysema, heart condition, pulmonary embolism, pulmonary oedema or SIPE, high blood pressure, diabetes, pneumonia, any other condition (to be specified in a free text response), or no health conditions. Pre-race questionnaire testing respondents were asked slightly different questions about their medical history. Firstly, they were asked to select which of the following health conditions they currently had: high blood pressure, diabetes, asthma, nasal allergy, Raynaud's syndrome, heart failure or other heart trouble (to be specified), other (to be specified), or no health conditions. Then they were asked if they had ever had any of the following: panic attack, pulmonary oedema, pulmonary embolism, angina, pneumonia, or none of the above.

6.2.6 Response bias

There was a risk of response bias whereby people may have been more likely to complete the survey if they had experienced SIPE, which could have led to inflated estimates. I addressed this by describing the surveys in broad terms as health surveys for outdoor swimmers. As is often the case with online surveys, I identified a risk of achieving very low response rates, which can increase the risk of nonresponse bias whereby nonresponse is unequally distributed among potential participants. I attempted to minimise this risk by using participant incentives such as prize draws. In order to identify duplicate responses and minimise the risk of double counting of respondents, I collected email addresses in the questionnaire.

6.2.7 Study size

I carried out a priori sample size calculations based on a confidence level of 0.95, power of 0.8, estimated exposure of controls of 40% and a minimum detectable effect size of 2. Using the following Fleiss methodology the results suggested that at least 88 cases of SIPE and 263 controls would be required; at total sample size of 351.

$$n_1 = \frac{\left[Z_{\alpha/2}\sqrt{(r+1)\overline{pq}}\right] + Z_{1-\beta}\sqrt{rp_1q_1 + p_2q_2}\Big]^2}{r(p_1 - p_2)^2}$$

$$n_2 = rn_1$$

Where

n_1 = number of cases

n_2 = number of controls

$Z_{\alpha/2}$ = standard normal deviate for two-tailed test based on alpha level (relates to the CI level)

Z_{β} = standard normal deviate for one-tailed test based on beta level (relates to the power level)

r = ratio of controls to cases

p_1 = proportion of cases with exposure and $q_1 = 1 - p_1$

p_2 = proportion of controls with exposure and $q_2 = 1 - p_2$

$\overline{p} = \frac{p_1 + rp_2}{r+1}$ and $\overline{q} = 1 - \overline{p}$

6.2.8 Quantitative variables

Reported height and weight values were cleaned and transformed from string to continuous variables. I then converted imperial height measurements to metres (for BMI calculations) and centimetres (for regression analyses) and weight values to kilograms. I excluded extreme outliers from the analyses as they were most likely to be data entry errors and could lead to potentially inaccurate or misleading results. These were identified through visual inspection of histograms and became missing values. The cleaned height and weight measurements were used to calculate BMI using the following formula:

$$BMI = \frac{weight\ (kg)}{heigh\ \ (m)^2}$$

I converted cleaned height values into a categorical variable to make the results of logistic regression analyses easier to interpret, using frequency histograms and descriptive statistics to determine appropriate cut-off points. Category parameters were kept wide enough to minimise the risk of small and sparse data effects that can reduce the performance of maximum likelihood prediction models (van Smeden *et al.* 2019). I created a categorical BMI variable from BMI values using the following categories; underweight/lower end of healthy weight (BMI<22), upper end of healthy weight (BMI 22<25) and overweight/obese respondents (BMI≥25). These categories were chosen instead of the accepted boundaries of BMI summarising i.e. underweight, healthy weight, overweight and obese, as a way of identifying leaner competitors, since there were very few underweight competitors (*n*=6).

Water temperature string values were cleaned and used to generate a new continuous variable. I also created a new water temperature categorical variable using a similar method to that described above for height to enable more straightforward interpretation of logistic regression analyses.

6.2.9 Statistical methods

Data from the surveys were exported from Qualtrics into Excel. Unique identifiers were added to all responses and variable names shortened to allow the data to be imported into Stata. Analyses were then carried out using Stata/IC 16 (StataCorp 2016. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.). For event surveys, data files for pre-race and post-race responses from the same person were merged using email addresses as person identifiers. The resulting datasets contained both long term risk factor variables from pre-race survey questions and triggers from post-race survey questions. Some responses could not be matched because the respondent had completed only one of the event surveys. These responses were included in the dataset, but with missing data for the variables included in the survey that was not completed. Data for each event were then appended to form a single large event survey dataset. This was then appended to data collected in the outdoor swimming survey and from questionnaire testing (see flowchart in Figure 6). Where an individual had completed the questionnaire more than once, the response that was most complete was included in the dataset, or if both were similarly complete, the response that had been completed earlier was included. Incomplete responses where the respondent did not progress beyond the first question were not included. The data were then further cleaned and coded in preparation for analysis. Descriptive statistics were produced for age band, sex, ethnicity, region of residence and type of swimmer, as well as any health conditions. Descriptive statistics for quantitative variables such as height, weight, BMI and water temperature were also reported. Outlier values for quantitative variables were excluded from the analysis. Missing data were included in all descriptive statistics.

I produced contingency tables for each categorical variable, re-categorising, if possible, in the case of low frequency cells of <10 to avoid the adverse effects of small and sparse data on the performance of maximum likelihood prediction models. Unadjusted ORs were calculated for all risk factors using univariate logistic regression. Effect size was judged using the following criteria set by Chen, Cohen and Chen (2010) for use in epidemiological studies; OR<1.68 (very small),1.68<3.47 (small), 3.46<6.71 (medium) and ≥6.71 (large).

I calculated age and sex adjusted ORs in order to control for their confounding effect. For age adjustment I used the dichotomous variable of age>40. I calculated sex specific univariate ORs for height and BMI. I reported 95% confidence intervals and *p*-values. *P*-values for trend using the Cochran–Armitage test were calculated where adjusted ORs for ordinal variables signalled a possible trend. For continuous variables I produced scatterplots against SIPE probability and added a lowess curve to visualise the trend. I then used the Box-Tidwell test to check if the assumption of linearity was met. I carried out further investigations into the risk factors that were found to be significant, exploring potentially confounding variables through including them in multivariate models and noting their effects on ORs, 95% confidence intervals and *p*-values.

6.3 Results

6.3.1 Participants

In total, 176 responses were received from event surveys, 1,155 from the outdoor swimming survey and 25 from the questionnaire testing phase. After excluding minimally completed responses (where the respondent either failed to answer the first question or didn't progress beyond it), appending datasets and removing duplicates, there were 1,113 responses remaining from which to select cases and controls. Respondents that met the case definition (described in section 6.2.3) were categorised as SIPE cases, and those that had not experienced any SOB were controls. I excluded 133 responses where the respondent reported experiencing SOB, but did not meet the SIPE case definition i.e. where the respondent believed the SOB may have been caused by inhaling water and/or it happened immediately on entering the water, and they didn't see a doctor who thought the SOB could have been SIPE. The final sample for the case control study included 107 SIPE cases and 873 controls; a total of 980 responses. Table 28 shows details of the recruitment of cases and controls from the event surveys. Table 29 shows similar information for the outdoor swimming survey and questionnaire tests.

Table 28: Recruitment of cases and controls from event surveys

Event	Total responses		Minimally completed[1]		Responses remaining		Responses in merged dataset	Duplicates removed	Sample for case and control selection
	Pre	Post	Pre	Post	Pre	Post			
Hever Castle Triathlon	43	108	4	10	39	98	112[2]	2	110
Hever Castle Festival of Endurance	10	9	0	0	10	9	12[3]	0	12
London Triathlon	5	1	1	0	4	1	4[4]	0	4
Total	58	118	5	10	53	108	128	2	126

[1] where respondent either failed to answer the first question or didn't progress beyond the first question; [2] 25 respondents completed both pre- and post-race survey; [3] 7 respondents completed both pre- and post-race survey; [4] 1 respondent completed both pre- and post-race survey

Table 29: Recruitment of cases and controls from outdoor swimming survey and questionnaire testing

Survey	Total responses	Excluded responses: Minimally completed	Excluded responses: Duplicates	Sample for case and control selection
Outdoor swimming survey	1,155	163	28	964
Questionnaire testing	25	0	2	23
Total	1,180	163	30	987

Table 30 and Figure 6 show all routes of recruitment to case and control groups. Fisher's Exact test indicated a significant difference in routes of recruitment for cases and controls at $p<0.001$). Cases were more likely than controls to be recruited through questionnaire tests (9.4% vs 1.3% respectively) and controls were more likely to be recruited from Hever Castle Triathlon than cases (10.7% vs 3.7% respectively).

Table 30: Recruitment of cases and controls for risk factor sample

Event	Cases (%)	Controls (%)	Neither case nor control (%)	Risk factor sample (%)
Hever Castle Triathlon	4 (3.7)	93 (10.7)	13 (9.9)	97 (9.9)
Hever Castle Festival of Endurance	0 (0.0)	11 (1.3)	1 (0.8)	11 (1.1)
London Triathlon	0 (0.0)	4 (0.5)	0 (0.0)	4 (0.4)
Outdoor swimming survey	93 (86.9)	752 (86.3)	119 (89.5)	845 (86.2)
Questionnaire testing	10 (9.4)	13 (1.3)	0 (0.0)	23 (2.3)
Total	107 (100.0)	873 (100.0)	133 (100.0)	980 (100.0)

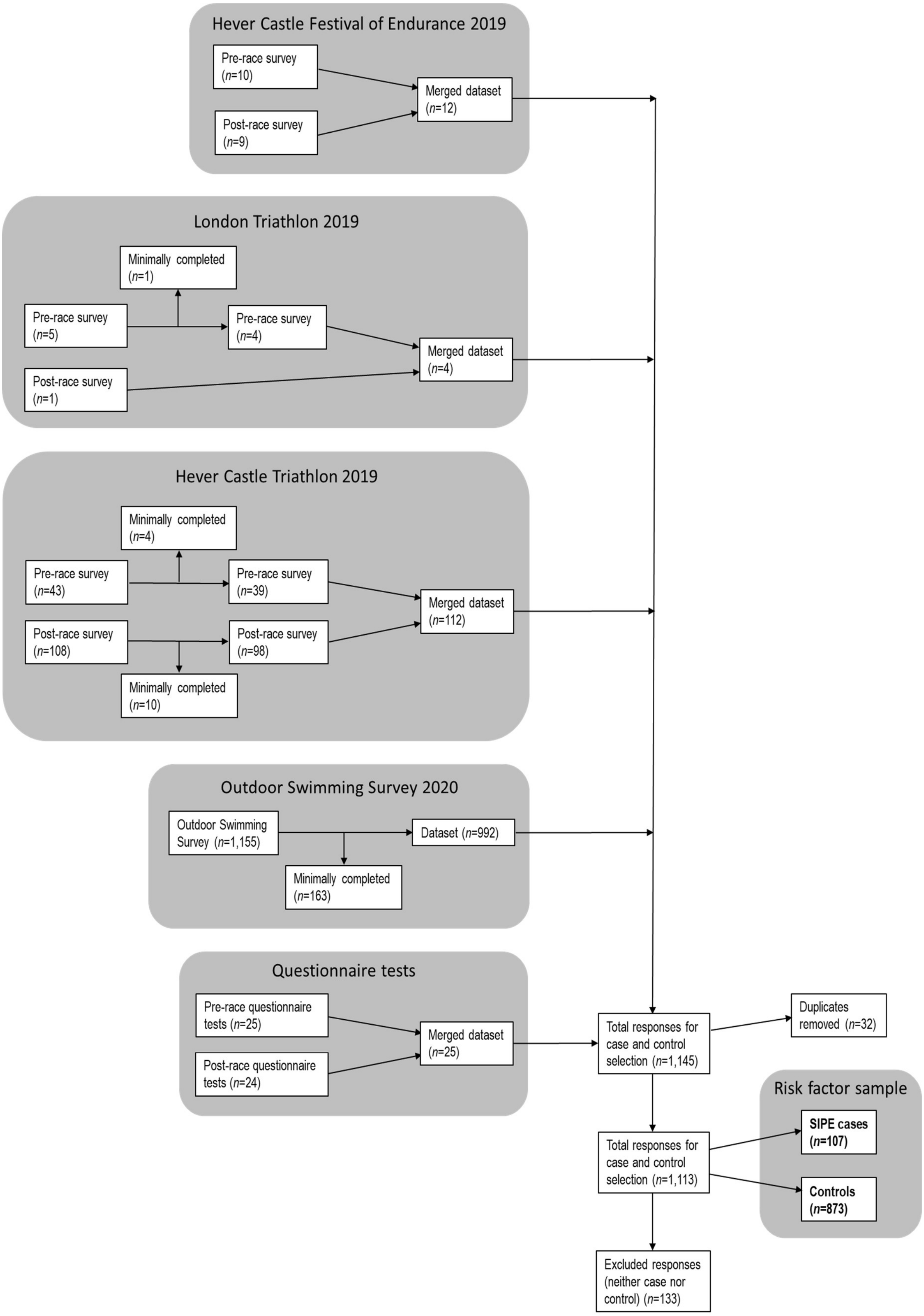

Figure 6: Flowchart showing routes of recruitment to case and control groups

6.3.2 Risk factors

6.3.2.1 Age, sex and ethnicity

Table 31 shows distribution of age, sex and ethnicity for cases and controls, as well as crude and adjusted ORs for SIPE for these variables. The majority of cases and controls were aged 40–59, over two thirds were female and almost all were of White ethnicity. All adjusted regression models controlled for both age and sex, apart from the age and sex models that adjusted for either age or sex. I included a binary age variable of <40 versus ≥40 years in all age-adjusted models to minimise the risk of very low cell counts in the OR table. The ORs suggest that age or sex were not risk factors for SIPE. There was only one non-White SIPE case, which meant that I could not assess ethnicity as a risk factor for SIPE.

Table 31: Demographics of respondents included in the risk factor sample and association with SIPE

Variable	Controls (%) (*n*=873)	Cases (%) (*n*=107)	Crude analysis Odds ratio (95% CI)	*p*	Adjusted for age and/or sex Odds ratio (95% CI)	*p*
Age (years)						
<40	228 (25.8)	25 (25.8)	1		1	
40-49	287 (32.9)	35 (32.9)	1.11 (0.65 to 1.91)	0.70	1.12 (0.65 to 1.93)	0.67
50-59	260 (29.8)	32 (29.8)	1.12 (0.65 to 1.95)	0.68	1.13 (0.65 to 1.97)	0.67
≥60	88 (10.1)	12 (10.2)	1.14 (0.60 to 2.58)	0.56	1.24 (0.60 to 2.58)	0.56
Data missing	10 (1.2)	3 (1.3)				
Sex						
Male	273 (31.3)	35 (32.7)	1		1	
Female	585 (67.0)	69 (64.5)	0.92 (0.60 to 1.42)	0.71	0.92 (0.60 to 1.41)	0.70
Other/prefer not to say/ missing	15 (1.7)	3 (2.8)				
Ethnicity						
White	838 (96.0)	103 (96.3)	1		1	
All other groups	18 (2.1)[1]	1 (0.9)[2]	0.45 (0.06 to 3.42)	0.44	0.45 (0.06 to 3.38)	0.44
Prefer not to say/missing	17 (2.0)	3 (2.8)				

[1] includes Mixed (n=15), Black/Black British (n=1), and Chinese or other ethnicity (n=2); [2] Mixed ethnicity

6.3.2.2 Height, weight and BMI

Descriptive statistics for the continuous height, weight and BMI variables (excluding outlier values) are shown separately for men and women in Table 32. Extreme outliers that were removed included one woman that reported a height of above 6ft 5 inches, another who said she weighed 730 kg and 28 respondents whose calculated BMI was ≥50 kg/m^2. Both mean and median are included in the table as measures of central tendency. Height, weight and BMI of cases and controls were fairly similar apart from weight values for females, which were noticeably higher in controls compared to cases. Median heights for all males and females were slightly above the published mean recorded heights for men and women in England of 175.5 cm and 161.7 cm respectively (NHS Digital 2022). According to median weight values, all male and female respondents were lighter than the national means of 85.4 kg and 72.1 kg respectively (NHS Digital 2022). The median BMI of 25–26 kg/m^2 for both males and females was below the national published figures of 27.6 kg/m^2 for men and women (NHS Digital 2022).

Table 32 Descriptive statistics for anthropometric variables

	Controls					Cases				
Variable	***N***	**Mean**	**SD**	**Median**	**Range**	***N***	**Mean**	**SD**	**Median**	**Range**
Females										
Height (cm)	584	167.1	6.6	167.6	148.0–195.7	69	165.7	6.9	165.2	150.0–180.4
Weight (kg)	578	74.0	16.6	70.0	47.0–180.0	69	69.5	14.8	65.0	46.0–139.7
BMI (kg/m^2)	572	26.2	5.1	25.0	17.3–45.2	69	25.3	5.1	24.5	18.0–46.8
Males										
Height (cm)	273	179.9	7.6	180.4	138.0–208.2	34	178.3	8.6	180.0	153.0–193.0
Weight (kg)	273	84.3	13.7	82.0	48.5–150.0	34	84.4	14.8	84.8	53.0–140.0
BMI (kg/m^2)	273	26.1	4.1	25.1	17.9–47.3	33	26.7	4.7	25.6	20.3–41.7

BMI = body mass index

Table 33 shows crude and adjusted ORs for SIPE for both continuous and categorical BMI and height data. Although not statistically significant at $p<0.05$, I found there was a 3% reduction in the odds of SIPE for every increase in height of 1 cm among women. A Box-Tidwell test confirmed the assumption of linearity between female height and the logit of SIPE was met. My logistic regression analyses using the ordinal height variable signalled an increase in the odds of SIPE in shorter women i.e. <160 cm tall compared to ≥170 cm, although, again, the effect was not significant at $p<0.05$. However, the *p* value for trend was 0.136 and observed power was 0.4, which suggests there might be a trend if the sample size was bigger.

My logistic regression results that used the continuous female BMI variable as a predictor signalled a decrease in the odds of SIPE as BMI increased, although the association was not statistically significant at $p<0.05$. For every increase in BMI of 1 kg/m^2, the odds of SIPE fell by 3%. A scatterplot of female BMI against probability of SIPE with lowess curve showed the relationship was linear for people with a BMI of 22–32, after which the probability fell gradually. A Box-Tidwell test indicated the assumption of a linear relationship between female BMI and the logit of SIPE had been met. Logistic regression analyses using the ordinal female BMI variable showed that women with a BMI<22 were at a significantly greater risk of SIPE compared to those with a BMI≥25. A Cochran-Armitage test produced a linear trend *p* value of just below 0.05 significance level indicating there was weak evidence for a linear trend in SIPE ORs across female BMI categories. I found no significant relationship between male height or BMI and SIPE.

Table 33: Height, weight and BMI of respondents and association with SIPE

Variable	Controls (%) (*n*=873)	Cases (%) (*n*=107)	Crude analysis Odds ratio (95% CI)	*p*	Adjusted for age and sex Odds ratio (95% CI)	*p*
Height (cm)						
Female						
Continuous variable	584 (99.8)	69 (100.0)	0.97 (0.93 to 1.01)	0.09	0.97 (0.93 to 1.01)	0.10
<160	62 (10.6)	12 (17.4)	1.81 (0.86 to 3.82)	0.12	1.80 (0.85 to 3.79)	0.13
≥160<165	130 (22.2)	17 (24.6)	1.22 (0.63 to 2.36)	0.55	1.22 (0.63 to 2.36)	0.55
≥165<170	168 (28.7)	16 (23.2)	0.89 (0.46 to 1.73)	0.73	0.89 (0.46 to 1.72)	0.72
≥170	224 (38.3)	24 (34.8)	1		1	
Data missing	1 (0.2)	0 (0.0)				
Male						
Continuous variable	273 (100.0)	34 (97.1)	0.98 (0.93 to 1.02)	0.26	0.98 (0.93 to 1.02)	0.26
<175	49 (18.0)	6 (17.1)	1.09 (0.41 to 2.89)	0.87	1.09 (0.41 to 2.90)	0.86
≥175<180	64 (23.4)	10 (28.6)	1.39 (0.61 to 3.17)	0.44	1.39 (0.61 to 3.17)	0.44
≥180	160 (58.6)	18 (51.4)	1		1	
Data missing	0 (0.0)	1 (2.9)				
BMI (kg/m^2)						
Female						
Continuous variable	572 (97.8)	69 (100.0)	0.96 (0.91 to 1.02)	0.16	0.96 (0.91 to 1.01)	0.15
<22	101 (17.3)	20 (29.0)	1.94 (1.05 to 3.58)	0.03	1.96 (1.06 to 3.62)	0.03
≥22<25	187 (32.0)	20 (29.0)	1.05 (0.58 to 1.91)	0.88	1.05 (0.58 to 1.91)	0.87
≥25	284 (48.6)	29 (42.0)	1		1	
Data missing	13 (2.2)	0 (0.0)				
Male						
Continuous variable	273 (100.0)	33 (94.3)	1.03 (0.95 to 1.12)	0.42	1.03 (0.95 to 1.12)	0.44
<22	24 (8.8)	4 (11.4)	1.18 (0.37 to 3.74)	0.79	1.20 (0.37 to 3.86)	0.76
≥22<25	108 (39.6)	9 (25.7)	0.59 (0.26 to 1.34)	0.21	0.59 (0.26 to 1.36)	0.22
≥25	141 (51.7)	20 (57.1)	1		1	
Data missing	0 (0.0)	2 (5.7)				

BMI = body mass index

6.3.2.3 Smoking and alcohol

The frequency of alcohol consumption variable included one category for those who had not consumed any alcohol in the previous six months (non-drinkers) and four ordered categories for those who had consumed alcohol (drinkers). All drinker categories showed very similar ORs for SIPE, and were notably lower than the reference category of non-drinkers. Therefore, I created a new binary alcohol consumption variable of non-drinkers versus drinkers (see Table 34). Non-drinkers were in the minority for both cases and controls, at 15% and 8% of respectively. The non-drinker group included a higher proportion of over 40's and lower proportion of women compared to the drinker group. However, the two groups were similar in terms of wetsuit use, asthma diagnosis, exertion levels, swimming distance and water temperatures. The adjusted model suggested that not drinking alcohol in the last six months increased the odds of SIPE.

Table 34: Smoking and alcohol consumption habits, and association with SIPE

	Controls (%)	Cases (%)	Crude analysis		Adjusted for age and sex	
Variable	**(*n*=873)**	**(*n*=107)**	**Odds ratio (95% CI)**	***p***	**Odds ratio (95% CI)**	***p***
Smoking habits						
Never smoked	480 (55.0)	62 (57.9)	1		1	
Ever smoked	385 (44.1)	42 (39.3)	0.84 (0.56 to 1.28)	0.42	0.83 (0.55 to 1.26)	0.39
Data missing	8 (0.9)	3 (2.8)				
Alcohol consumption in last 6 months						
Drinker	789 (90.4)	88 (82.2)	1		1	
Non-drinker	74 (8.5)	16 (15.0)	1.94 (1.08 to 3.47)	0.03	1.96 (1.09 to 3.52)	0.03
Data missing	10 (1.2)	3 (2.8)				

6.3.2.4Health conditions and medications

Table 35 shows the most frequently reported chronic health conditions. Conditions affecting very low numbers of respondents or those with no plausible mechanism for SIPE were excluded from the analysis. Atopic diseases such as asthma and nasal allergies were common among respondents, with a quarter having had a diagnosis of at least one of them. Asthma and nasal allergies often occur together (Brożek *et al.* 2017) which was the case for 8% of respondents (*n*=78). The regression analyses showed that cases and controls with diagnosed asthma or nasal allergies had greater odds of SIPE compared to those without. Asthma showed the strongest effect. The ORs for other health conditions indicated that a diagnosis of panic attack or cardiovascular diseases such as hypertension, cardiac dysfunction, or Raynaud's syndrome did not increase the odds of having experienced SIPE. I hypothesised that there may be more people with Raynaud's syndrome who had not had an official diagnosis, so I conducted further analyses into whether respondents reported having experienced Raynaud's symptoms. The results suggested that 25% of cases (*n*=27) had experienced Raynaud's symptoms compared to 19% of controls (*n*=165).

Table 35: Diagnosed health conditions and association with SIPE

	Controls (%)	Cases (%)	Crude analysis		Adjusted for age & sex	
Health condition	**(*n*=873)**	**(*n*=107)**	**Odds ratio (95% CI)**	***p***	**Odds ratio (95% CI)**	***p***
Atopic disease[1]						
No	649 (74.3)	63 (58.9)	1		1	
Yes	210 (24.1)	40 (37.4)	1.96 (1.28 to 3.00)	<0.01	1.97 (1.28 to 3.03)	<0.01
Data missing	14 (1.6)	4 (3.7)				
Asthma						
No	723 (82.8)	68 (63.6)	1		1	
Yes	143 (16.4)	37 (34.6)	2.75 (1.77 to 4.27)	<0.01	2.70 (1.73 to 4.21)	<0.01
Data missing	7 (0.8)	2 (1.9)				
Nasal allergy						
No	733 (84.0)	80 (74.8)	1		1	
Yes	125 (14.3)	23 (21.5)	1.69 (1.02 to 2.78)	0.04	1.76 (1.06 to 2.92)	0.03
Data missing	15 (1.7)	4 (3.7)				
Cardiovascular disease[2]						
No	744 (85.2)	89 (84.2)	1		1	
Yes	125 (14.3)	17 (15.9)	1.14 (0.65 to 1.98)	0.65	1.05 (0.60 to 1.86)	0.85
Data missing	4 (0.5)	1 (0.9)				
Hypertension						
No	800 (91.6)	98 (91.6)	1		1	
Yes	63 (7.2)	6 (5.6)	0.78 (0.33 to 1.84)	0.57	0.75 (0.31 to 1.80)	0.52
Data missing	10 (1.2)	3 (2.8)				
Heart condition						
No	836 (95.8)	97 (90.7)	1		1	
Yes	26 (3.0)	7 (6.5)	2.32 (0.98 to 5.49)	0.06	1.89 (0.75 to 4.76)	0.17
Data missing	11 (1.3)	3 (2.8)				
Raynaud's syndrome						
No	823 (94.3)	101 (94.4)	1		1	
Yes	42 (4.8)	4 (3.7)	0.78 (0.27 to 2.21)	0.65	0.80 (0.28 to 2.28)	0.67
Data missing	8 (0.9)	2 (1.9)				
Other health condition						
Panic attack						
No	814 (93.5)	97 (90.7)	1		1	
Yes	45 (5.2)	6 (5.6)	1.12 (0.47 to 2.69)	0.80	1.18 (0.49 to 2.88)	0.71
Data missing	12 (1.4)	4 (3.7)				

[1] Asthma or nasal allergy reported; [2] Hypertension, heart condition or Raynaud's syndrome reported

Table 36 shows the most frequently reported regular medications and supplements. Forty-four percent of respondents reported taking medications and supplements regularly, however, I found no significant associations between medication/supplement use and SIPE.

Table 36: Regular medication and health supplements and association with SIPE

Medication/supplement	Controls (%) (*n*=873)	Cases (%) (*n*=107)	Crude analysis		Adjusted for age & sex	
			Odds ratio (95% CI)	*p*	Odds ratio (95% CI)	*p*
Anti-platelet drugs[1]						
No	838 (96.0)	100 (93.5)	1		1	
Yes	26 (3.1)	2 (1.9)	0.64 (0.15 to 2.76)	0.56	0.64 (0.15 to 2.72)	0.54
Data missing	9 (0.8)	5 (4.7)				
Supplements with antiplatelet activity[2]						
No	693 (79.4)	83 (77.6)	1		1	
Yes	171 (19.6)	19 (17.8)	0.93 (0.55 to 1.57)	0.78	0.93 (0.55 to 1.58)	0.79
Data missing	9 (1.0)	5 (4.7)				
Antihypertensive drugs						
No	834 (95.5)	95 (88.8)	1		1	
Yes	30 (3.4)	7 (6.5)	2.05 (0.88 to 4.79)	0.10	2.00 (0.85 to 4.71)	0.11
Data missing	9 (1.0)	5 (4.7)				
Sex hormones in women[3]						
No	560 (95.7)	67 (97.1)	1		1	
Yes	25 (4.3)	2 (2.9)	0.67 (0.15 to 2.89)	0.59	0.68 (0.16 to 2.94)	0.61
Data missing	0 (0.0)	0 (0.0)				

[1] e.g. NSAIDS, aspirin, clopidogrel; [2] e.g. omega-3 oils, turmeric, vitamin C (on its own or part of multivitamin); [3] Out of a total of 654 women (585 controls and 69 cases)

6.3.2.5Water temperature

Table 37 includes descriptive statistics for water temperatures estimated by respondents for either their last outdoor swim (controls) or the swim during which they had their last episode of SIPE (cases). Three water temperature values were below freezing (-4°C, -2°C and -1°C), which seemed unusually low for UK water bodies, suggesting a high potential for misclassification. I consulted minimum river temperature data for England and Wales for 1990–2007 reported by Cooper (2010) cited in Orr *et al.* (2010) to check if these values were indeed likely to have been inputted in error. The mean minimum water temperature value reported by Cooper (2010) was 1.09°C (SD=1.2), which suggested misclassification may have occurred with regard to the three coldest temperatures. After excluding these three values from the analysis, the remaining estimated water temperatures ranged from 1.5°C to 26.0°C.

Table 37: Descriptive statistics for continuous water temperature variable

Group	*N*	Mean (°C)	SD (°C)	Median (°C)	Range (°C)
Controls	840	9.8	4.9	8.0	1.5–26.0
Cases	99	12.0	5.2	12.0	1.0–24.0

Table 38 contains categorical water temperature data, as well as the results of adjusted and unadjusted logistic regression analyses using categorical and continuous variables. It shows controls were much more likely to report having swum in water of <12°C compared to cases. The results of analyses using continuous water temperature data indicated there was a significant association between water temperature and SIPE, with every increase in water temperature of 1°C resulting in odds of SIPE increasing by 8%. This positive association was shown in a scatterplot of SIPE probability against water temperature, by an upward sloping lowess curve from around 6°C degrees onwards, with slope increasing from around 18°C. The results of a Box-Tidwell test suggested the assumption of linearity between water temperature and the logit of SIPE was met.

When I carried out logistic regression modelling using the ordinal water temperature variable, I found that swimming in water temperatures of 12<18 and ≥18°C increased the odds of SIPE, compared to swimming in water of <12°C. The trend across temperature categories was significant at $p<0.001$, with the effect being the greatest in water temperatures of ≥18°C. A scatterplot of SIPE probability against water temperature categories illustrates this positive association (see Figure 7). However, it should be noted that the high potential for confounding and misclassification of the water temperature variable means these results can only provide weak evidence for an association with SIPE.

Table 38: Estimated water temperature categories and association with SIPE

Water temperature (°C)	Controls (%) (*n*=873)	Cases (%) (*n*=107)	Crude analysis		Adjusted for age and sex	
			Odds ratio (95% CI)	*p*	Odds ratio (95% CI)	*p*
Continuous variable	840 (96.2)	99 (92.5)	1.09 (1.04 to 1.13)	<0.01	1.08 (1.04 to 1.13)	<0.01
<12	541 (62.0)	42 (39.3)	1		1	
≥12<18	232 (26.6)	43 (40.2)	2.39 (1.52 to 3.75)	<0.01	2.38 (1.49 to 3.80)	<0.01
≥18	67 (7.7)	14 (13.1)	2.69 (1.40 to 5.19)	<0.01	2.52 (1.27 to 5.00)	<0.01
Data missing	33 (3.8)	8 (7.5)				

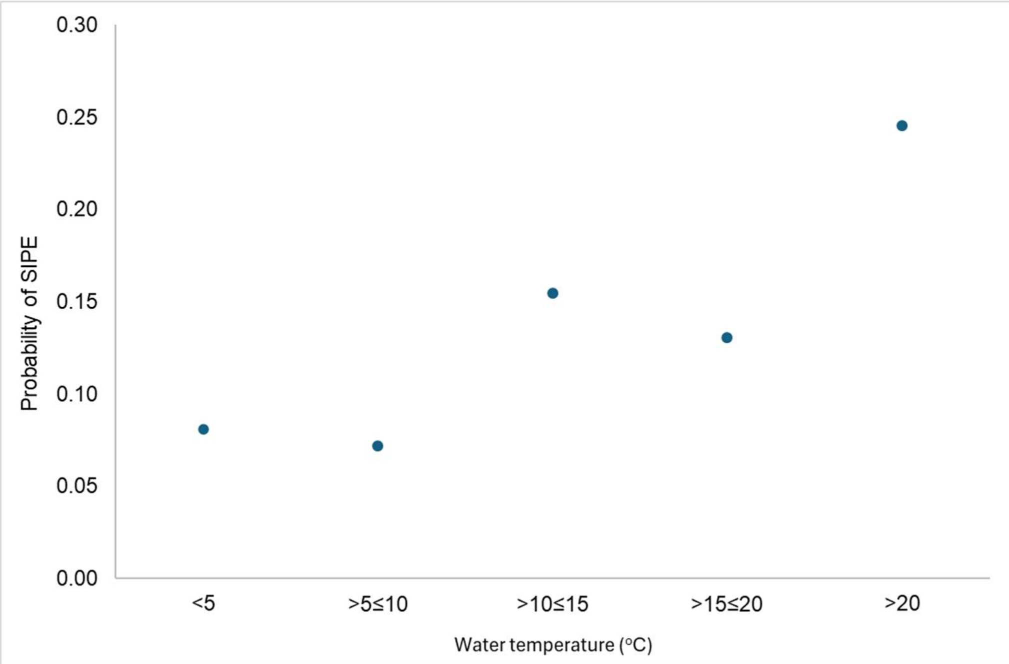

Figure 7: Scatterplot of SIPE probability against water temperature

6.3.2.6 Swimming behaviours

Table 39 includes information on swimming behaviours and their associations with SIPE. The results for each variable separately are described below.

Wetsuit use

Wetsuit use was less common among controls, with 46% reporting wearing a wetsuit during their last outdoor swim compared to 66% of cases who wore a wetsuit the last time they experienced SIPE. My analysis showed that wearing a wetsuit (in particular a tight wetsuit) versus no wetsuit increased the odds of SIPE. The trend across the ordered categories of no wetsuit, non-tight wetsuit, and tight wetsuit, was highly significant ($p<0.001$). It was not possible to explore the effect of shorty or short sleeved/sleeveless wetsuits because only five SIPE cases reported wearing them.

Exertion

There was a high potential for misclassification of maximum effort levels due to the subjective nature of the question, therefore I created a binary variable for maximum effort <50% vs ≥50%. Over

86% of cases reported maximum effort levels of ≥50% the last time they had SIPE, compared to 75% of controls whose maximum effort levels were ≥50% during their last swim. The adjusted analysis showed that those who reported effort levels ≥50% had a higher risk of experiencing SIPE.

Swimming distance

Over 60% of respondents swam ≥500m the last time they swam outdoors (outdoor swimming survey respondents) or entered a swimming race of ≥500m (event survey respondents). There was a slight increase in the risk of SIPE as swimming distances increased, however the ORs and trend were not statistically significant at $p<0.05$.

Type of swimmer

The majority of respondents (64%) were classified as swimmers only, in other words they did not report taking part in a triathlon or multisport race involving cycling or running in addition to swimming. The results signalled a possible increased risk in multisport swimmers, although this was effect was not significant at $p<0.05$. Observed power was 0.21 which indicates a low probability of detecting a true effect if one exists.

Swimming months and frequency

Over three quarters of respondents said they swam all year round i.e. including the colder months of January to April, and over two thirds had swum over 20 times in the last 12 months. Neither of these variables were associated with SIPE.

Pre-swim drink consumed

The pre-swim volume of fluid consumed variable showed a high potential for misclassification due to the risk of respondents over or underestimating the volume of drink they consumed. Furthermore, this variable was not an accurate measure of hydration status of an individual due the multiple factors involved in determining the balance between fluid intake and fluid lost through sweat and urine e.g. body composition, exertion level, physical fitness, wetsuit use and environmental conditions. Therefore, I created a binary variable for pre-swim drink versus no pre-swim drink (see Table 39). Almost three quarters of controls reported having a pre-swim drink compared to 61% of cases. The results of the adjusted regression analysis showed no significant association between having a pre-swim drink and SIPE at $p<0.05$, although they signalled a possible reduced risk of SIPE among those who had a drink compared to those who did not. I calculated observed power as 0.69, which suggests that a larger sample size may have resulted in a statistically significant association.

Table 39: Swimming behaviours and association with SIPE

Swimming behaviour	Controls (%) (*n*=873)	Cases (%) (*n*=107)	Crude analysis Odds ratio (95% CI)	*p*	Adjusted for age and sex Odds ratio (95% CI)	*p*
Wetsuit use						
No	455 (52.1)	33 (30.8)	1		1	
Yes	402 (46.1)	71 (66.4)	2.44 (1.58 to 3.76)	<0.01	2.55 (1.62 to 4.00)	<0.01
Data missing	16 (1.8)	3 (2.8)				
Tight wetsuit use						
No wetsuit	455 (52.1)	33 (30.8)	1		1	
Not tight wetsuit	333 (38.1)	44 (41.1)	1.82 (1.14 to 2.92)	0.01	1.87 (1.14 to 3.04)	0.01
Tight wetsuit	60 (6.9)	23 (21.5)	5.29 (2.91 to 9.60)	<0.01	5.83 (3.15 to 10.80)	<0.01
Data missing	25 (2.9)	7 (6.5)				
Maximum effort (%)						
<50	201 (23.0)	11 (10.3)	1		1	
≥50	654 (74.9)	93 (86.9)	2.60 (1.36 to 4.95)	<0.01	2.59 (1.34 to 4.97)	<0.01
Data missing	18 (2.0)	3 (2.8)				
Pre-swim drink						
No	202 (23.1)	31 (29.0)	1		1	
Yes	641 (73.4)	65 (60.8)	0.66 (0.42 to 1.04)	0.08	0.64 (0.41 to 1.02)	0.06
Data missing	30 (3.4)	11 (10.3)				
Type of swimmer						
Swimming only	570 (65.3)	60 (56.1)	1		1	
Multisport swimmer[1]	296 (33.9)	43 (40.2)	1.40 (0.92 to 2.13)	0.11	1.47 (0.94 to 2.29)	0.09
Data missing	7 (0.8)	4 (3.7)				
Distance of outdoor swim (m)						
<500	314 (36.0)	31 (29.0)	1		1	
≥500≤1000	229 (26.2)	27 (25.2)	1.19 (0.69 to 2.06)	0.52	1.15 (0.66 to 2.00)	0.61
>1000≤2000	176 (20.2)	21 (19.6)	1.21 (0.67 to 2.17)	0.53	1.23 (0.68 to 2.25)	0.49
>2000	135 (15.5)	19 (17.8)	1.43 (0.78 to 2.61)	0.25	1.41 (0.75 to 2.64)	0.28
Data missing	19 (2.2)	9 (8.4)				
Months of the year swam outdoors						
All year round	717 (82.1)	84 (78.5)	1		1	
May–Dec only	148 (17.0)	20 (18.7)	1.15 (0.69 to 1.94)	0.59	1.19 (0.70 to 2.03)	0.51
Data missing	8 (0.9)	3 (2.8)				
Outdoor swimming frequency in last 12 months						
0–9	124 (14.2)	14 (13.1)	1		1	
≥10–19	135 (15.5)	17 (15.9)	1.12 (0.53 to 2.36)	0.78	1.19 (0.56 to 2.56)	0.65
≥20	606 (69.4)	74 (69.2)	1.08 (0.59 to 1.98)	0.80	1.15 (0.61 to 2.16)	0.67
Data missing	8 (0.9)	2 (1.9)				

[1] Competitors of multisport races involving swimming (triathlon, aquathlon, aquabike) or who respondents who reported having taken part in a triathlon

6.3.2.7 Further investigations into significant risk factors

I found the following were significantly associated with ever having reported an episode of SOB with symptoms that suggested SIPE: wetsuit use (particularly tight wetsuits), diagnosed asthma or nasal allergy, higher exertion, warmer water temperature, lower BMI, and not drinking alcohol in the previous six months. I carried out further analyses to understand which of these associations were strong and remained the same after attempts to control for confounders.

Wetsuit use

In my adjusted analyses I found a significant association between wetsuit use (particularly tight wetsuits) and SIPE that was not due to confounding by age and sex. I considered the possibility that the SOB could have been directly caused by the wetsuit itself due to pressure exerted on the chest causing restricted breathing, an effect that has been reported in literature (Schellart and Sterk 2016; Marabotti *et al.* 2017; Tetzlaff and Thomas 2017). I carried out further analyses which showed that wetsuits were worn by 67 SIPE cases, 23 (34%) of whom reported it being very tight or restrictive. However, only five SIPE cases (7%) that wore a wetsuit thought it may have caused their SOB, and none saw a doctor to confirm this. This suggests that in most cases the SOB was not caused by chest restriction.

I then theorised that people who wore a wetsuit may have had different body characteristics or swimming behaviours compared to those who did not. For example, wetsuit wearers might have had a lower BMI (so could potentially have a greater vascular response to cold water), or they may have swum in warmer water or put more effort into swimming. I carried out supplementary analyses to explore if the association between wetsuit use and SIPE could be explained by maximum effort levels, BMI or water temperature, by including each of these variables, separately, in age and sex adjusted models. The results are shown in Table 40. When maximum effort was included, the OR deceased slightly but remained significant at $p<0.05$. This suggested exertion had a small confounding effect, but did not explain the association between wetsuit use and SIPE. Including water temperature in the adjusted model had a similar but slightly greater effect i.e. it decreased the OR and increased the p value slightly more, whilst remaining statistically significant. This indicated that water temperature had a slightly larger confounding effect than maximum effort, although it was also not responsible for the association between wetsuit use with SIPE. Investigations into the effect of BMI on wetsuit use ORs showed that BMI had little to no effect, suggesting it was not acting as a confounding variable.

Table 40: Results of adjusted models for wetsuit use and SIPE

Variables adjusted for	Odds ratio (95% CI)	*p*
Age, sex	2.55 (1.62 to 4.00)	<0.01
Age, sex, maximum effort>50%	2.27 (1.43 to 3.59)	<0.01
Age, sex, water temperature	1.88 (1.12 to 3.16)	<0.02
Age, sex, BMI	2.49 (1.57 to 3.96)	<0.01

I undertook further analyses to determine if the variables explored above may help to explain the association between wearing a tight wetsuit and SIPE i.e. were people who wore tight wetsuits more likely to swim at higher effort levels, in warmer water, or have a lower BMI? The results are shown in Table 41). When maximum effort was included in the adjusted model, the ORs for wearing a non tight or tight wetsuit decreased slightly but remained significant. This suggested higher effort levels may have had a small confounding effect, but did not explain the association between tight or non tight wetsuit use and SIPE. When water temperature was included in the age and sex adjusted model, the OR for non tight wetsuit decreased and became non-significant, suggesting water temperature may explain its association with SIPE. The OR for tight wetsuit decreased, although *p* remained highly significant indicating water temperature only had a small confounding effect on the association between tight wetsuit use and SIPE. BMI had little or no effect on ORs for tight or non tight wetsuit, suggesting it was not a confounder.

Table 41: Results of adjusted models for tight wetsuit use and SIPE

	Non tight wetsuit		Tight wetsuit	
Variables adjusted for	Odds ratio (95% CI)	*p*	Odds ratio (95% CI)	*p*
Age, sex	1.87 (1.14 to 3.04)	0.01	5.83 (3.15 to 10.80)	<0.01
Age, sex, maximum effort	1.67 (1.02 to 2.75)	0.04	2.17 (2.77 to 9.66)	<0.01
Age, sex, water temperature	1.36 (0.78 to 2.38)	0.28	4.74 (2.44 to 9.22)	<0.01
Age, sex, BMI	1.82 (1.10 to 3.01)	0.02	5.87 (3.14 to 10.97)	<0.01

Asthma

My results showed the risk of SIPE was greater among swimmers diagnosed with asthma compared to those without a diagnosis. I considered the possibility that my case definition lacked specificity and failed to differentiate between symptoms of SIPE versus asthma. However, further analyses showed that out of the 37 SIPE cases who had been diagnosed with asthma, less than half (n=18) believed their SOB was due to asthma, with just eight having seen a doctor who thought asthma was the cause. This means the majority of SIPE cases who had asthma, thought and/or were told by a doctor their SOB was due to something else.

I used multivariate modelling to explore whether the association between asthma and SIPE was because respondents with asthma were more likely to have nasal allergies, wear a wetsuit, swim in warmer water or put more effort into swimming. The results showed that including these variables in adjusted models had no substantial effect on the OR for asthma or associated p values (see Table 42). This suggested the effect of diagnosed asthma on SIPE risk was strong and robust to confounding by any of the variables tested.

Table 42: Results of adjusted models for asthma diagnosis and SIPE

Variables adjusted for	**Odds ratio (95% CI)**	***p***
Age, sex	2.70 (1.73 to 4.21)	<0.01
Age, sex, wetsuit use	2.99 (1.88 to 4.76)	<0.01
Age, sex, nasal allergy	2.69 (1.64 to 4.39)	<0.01
Age, sex, maximum effort	2.64 (1.69 to 4.14)	<0.01
Age, sex, water temperature	2.79 (1.75 to 4.44)	<0.01
Age, sex, BMI	2.82 (1.80 to 4.42)	<0.01

BMI = body mass index

BMI

My results showed there was an association between having a lower BMI (<22 kg/m^2) and SIPE compared to being overweight (BMI≥25 kg/m^2). I theorised this may be because swimmers with a lower BMI were more likely to wear a wetsuit, put in more effort, or swim in warmer water. When wetsuit use and water temperature were controlled for in multivariate models, ORs became lower and not statistically significant, which suggested wetsuit use and water temperature explained much of effect of BMI<22 (see Table 43). Maximum effort level was not found to be a significant confounding factor.

Table 43: Results of adjusted models for BMI<22 and SIPE

Variables adjusted for	**Odds ratio (95% CI)**	***p***
Age, sex	1.96 (1.06 to 3.62)	0.03
Age, sex, wetsuit use	1.59 (0.83 to 3.06)	0.17
Age, sex, maximum effort	1.75 (1.02 to 3.00)	0.04
Age, sex, water temperature	1.49 (0.84 to 2.64)	0.17

Water temperature

I carried out supplementary analyses to explore if the greater risk of SIPE associated with swimming in water temperatures of ≥12°C could be explained by greater use of wetsuits, higher exertion levels or lower BMI. My results showed that controlling for maximum effort and BMI did not reduce the size of the ORs, however, controlling for wetsuit use did reduce the size of the OR, meaning there was no effect of water temperature independent of wetsuit use (see Table 44). However, the OR for the water temperatures ≥18°C model that controlled for wetsuit use remained >2, suggesting there may be a slight residual effect even when wetsuit use was accounted for.

Table 44: Results of adjusted models for water temperature and SIPE

	≥12<18°C		**>18°C**	
Variables adjusted for	**Odds ratio (95% CI)**	***p***	**Odds ratio (95% CI)**	***p***
Age, sex	2.38 (1.49 to 3.80)	<0.01	2.52 (1.27 to 5.00)	<0.01
Age, sex, wetsuit use	1.63 (0.95 to 2.80)	0.07	2.04 (0.97 to 4.31)	0.06
Age, sex, maximum effort	2.08 (1.28 to 3.37)	<0.01	2.23 (1.11 to 4.47)	0.02
Age, sex, BMI	2.28 (1.42 to 3.67)	<0.01	2.30 (1.13 to 4.68)	0.02

BMI = body mass index

Exertion

SIPE risk was greater in those who reported effort levels ≥50% compared to those who put less effort into their swim. I speculated that those who exerted themselves more might be more likely to have asthma, wear wetsuits, swim in warmer water, or have a lower BMI. I created adjusted models incorporating each of these variables to see the effect (see Table 45 for results). When I controlled for water temperature, I found the OR reduced substantially and CI spanned one. This indicated that water temperature may explain the effect of higher exertion levels. Controlling for asthma, wetsuit use, or BMI (separately) also reduced the ORs for exertion, however all remained statistically significant at $p<0.05$. This meant a small amount of confounding may have occurred, but not enough to substantially weaken the association between maximum effort and SIPE.

Table 45: Results of adjusted models for maximum effort ≥50% and SIPE

Variables adjusted for	Odds ratio (95% CI)	*p*
Age, sex	2.59 (1.34 to 4.97)	<0.01
Age, sex, wetsuit use	2.00 (1.02 to 3.92)	<0.05
Age, sex, asthma	2.44 (1.26 to 4.71)	<0.01
Age, sex, water temperature	1.83 (0.92 to 3.64)	0.09
Age, sex, BMI	2.46 (1.27 to 4.74)	<0.01

BMI = body mass index

Alcohol consumption

The ordinal alcohol consumption variable showed no visible trend in the effect of alcohol consumption frequency on SIPE risk. This suggests there may have been something about non-drinkers other than their abstention from alcohol that increased their risk of SIPE compared to drinkers. I investigated whether the association might be due to increased wetsuit use, asthma or higher effort levels among non-drinkers by including each of these variables separately in age and sex adjusted predictive models. The results shown in Table 46 indicated that none of these factors reduced ORs to a non-significant level, in fact some strengthened the effect. This suggests the association between being a non-drinker and SIPE may be due to a characteristic of non-drinkers that was not measured in this study.

Table 46: Results of adjusted models for non-drinker and SIPE

Variables adjusted for	Odds ratio (95% CI)	*p*
Age, sex	1.96 (1.09 to 3.52)	0.03
Age, sex, wetsuit use	2.05 (1.12 to 3.77)	0.02
Age, sex, asthma diagnosis	1.95 (1.08 to 3.55)	0.03
Age, sex, maximum effort	1.99 (1.10 to 3.61)	0.02

6.3.2.8 Variables excluded from the analysis

I omitted two risk factor variables from the logistic regression analyses; nasal allergy diagnosis and nervousness whilst swimming. I excluded the nasal allergy diagnosis variable because it was highly collinear with asthma diagnosis, which meant the two effects could not be easily separated. Fifteen percent of respondents said they felt anxious or nervous during their last swim or the last time they had an episode of SIPE. However, the questionnaire did not ask if the nervousness occurred before or after the SOB started. Therefore, it was not possible to differentiate between swimmers whose feelings of anxiety preceded the episode of SIPE and those who became nervous because of SIPE symptoms. This means the results of any analyses would not have been useful.

6.4 Discussion

6.4.1 Key results

My analysis indicated that significant risk factors for having ever had SIPE included wearing a wetsuit (particularly a tight wetsuit) or having an asthma diagnosis. Higher effort levels, swimming in water temperatures of 12^{o}C and above, and having a BMI<22 kg/m^{2} were also associated with SIPE, however, further analyses showed these effects could be explained by confounding variables. Being a non-drinker was also associated with SIPE, although the absence of a visible trend in the effect of decreasing levels of alcohol consumption suggested the association was most likely due to a characteristic or behaviour of non-drinkers that I did not measure in this study. Surprisingly, I did not find age, sex, swimming distance, exertion, or a history of heart disease, hypertension or Raynaud's syndrome to be significantly associated with SIPE.

6.4.2 Limitations

These findings may have come about as a result of bias, which was defined by Šimundić (2013) as *"any trend or deviation from the truth in data collection, data analysis, interpretation and publication which can cause false conclusions"*. The main types of bias in epidemiological studies are information and selection bias. Information bias refers to the type of error that occurs when key information is either measured, collected or interpreted incorrectly. Information bias can be split into a number of categories including misclassification bias, observer bias, recall bias and reporting bias. Selection bias occurs when individuals included in the sample differ systematically from the population of interest.

6.4.2.1 Sources of information bias

The data collection process was subject to information bias, particularly exposure misclassification whereby respondents reported exposure levels that were different from their actual exposure. For example, respondents were asked if they had *ever* been diagnosed with a health condition, which could have included a diagnosis that was no longer current, such as childhood asthma or pregnancy related hypertension. Respondents were also asked to estimate the temperature of the water at the time of their last swim (controls) or when they last experienced SIPE (controls), which may not be accurate if they were not at an organised event or venue. Even if water temperatures were publicised on the day of the swim, they were likely to be a snapshot in time, often early in the morning, so may not be an accurate reflection of actual water temperature during the time of their swim.

Misclassification bias may also have been present for variables that fluctuate greatly over time, such as an individual's body weight or alcohol consumption habits. Evidence suggests there is a tendency among certain groups of people to over-report height and/or under-report weight (Danubio *et al.* 2008; Flegal *et al.* 2019), which would also have increased the risk of misclassification of reported heights and weights, and therefore calculated BMI values. Maximum effort level is a very subjective concept so would have been subject to differences in the perceptions of individuals, again leading to potential misclassification. The number of pre-swim drinks consumed was not an accurate measure of hydration status of an individual due the multiple factors involved in determining fluid balance in an individual.

Misclassification of outcomes may have been an issue, since the final version of the questionnaires did not undergo validation. However, earlier versions of the questionnaire indicated the SIPE case definition was reasonably sensitive and specific, so the risk of false positives or negatives should have been fairly minimal.

Recall bias is another type of information bias that could have occurred during data collection. Cases were asked to recall information about their last episode of SIPE and controls were asked about their most recent outdoor swim. Cases whose last episode of SIPE was fairly recent or memorable may be more likely to report accurate information than controls whose last swim was uneventful. The responses of cases may also have been influenced by any preconceived ideas about the factors that led them to experience SIPE.

6.4.2.2 Sources of selection bias

Cases and controls were both taken from the same survey sample, however, they were not randomly selected, therefore selection bias will be an issue. It could be argued the sample included two different populations of open water swimmers; triathletes and non-triathletes (outdoor swimmers who have not taken part in triathlons). These two groups tend to differ in body composition, swimming environments and swimming behaviours. For example, wetsuit use is more common among triathletes, however, my methods ensured that many of these differences were accounted for in the adjusted models.

There was a risk of double counting respondents if they had completed the surveys more than once. I attempted to minimise this type of selection bias by collecting email addresses and removing duplicates, however, this will not have identified respondents who provided a different email address in each response.

Carrying out multiple statistical analyses on the same sample increases the likelihood of a Type 1 (or family-wise) error occurring i.e. the probability of getting a “false positive”, where there appears to be a statistically significant effect when in fact there is not. There is no clear consensus on how much the error rate is affected or how to address this issue. The Bonferroni adjustment is often used in these circumstances, but has been applied inconsistently applied across literature. Therefore, I chose not to use it in my analysis, instead preferring to acknowledge the increased probability of a Type 1 error as a limitation in this study. Type 2 errors or the increased probability of "false negatives" where a statistically significant effect appears not to be significant, may have been caused by converting continuous values into categorical data.

6.4.2.3 Confounding

During my analysis I attempted to identify and adjust for confounding variables, however, this was limited by the data collected by the questionnaires. It was also difficult to separate the effects of variables that showed high collinearity, such as asthma diagnosis and asthma medications, and wetsuit use, water temperature, maximum effort level and swimming distance. There were a number of potential risk factors that were not part of the data collection so could not be accounted for, such as swimming stroke used, type of open water, type of swim i.e. race or casual swim, or mid-swim hydration/nutrition intake. In addition, the questionnaire did not ask the respondent to report any medications taken on the day of the swim that were not regular medications.

6.4.3 Interpretation

6.4.3.1 Wetsuit use

Wearing a wetsuit, particular one that was tight or restrictive, was strongly associated with having ever had SIPE. There are a number of reasons why respondents may have worn a wetsuit, for example if they were thin (and therefore more sensitive to the cold), if the water was very cold, or if they were swimming competitively rather than recreationally. There was also the risk of potential uncontrolled confounding by unknown factors.

I evaluated the evidence for a causal association between wetsuit use and SIPE using the nine Bradford Hill criteria (Hill, 1965). Hill suggests the strength of the association should be considered first, with strong associations more likely to suggest causation. Consistency is the next criterion, which asks whether the association has been observed repeatedly by different people at different times, and in different circumstances and places. The third criterion is specificity, which states the exposure should have only one effect. Temporality is a requirement for the exposure to precede the effect, and for the presence of a biological gradient i.e. exposure-response relationship, increases the likelihood of a causal association. The plausibility criterion states there should be a plausible biological mechanism although this is not a requirement. Coherence is concerned with whether the association fits with the existing literature. The experiment criterion asks if there are any RCTs or natural experiments which have provided compelling evidence of an association. The final consideration is termed “analogy” and questions if other similar exposures or risk factors have produced a similar outcome.

Strength of association

According to threshold values set by Chen, Cohen and Chen (2010), the association between SIPE and wearing a tight wetsuit was strong; for non-tight wetsuits the association was weak.

Consistency

These findings were consistent with those of Miller, Calder-Becker and Modave (2010) who reported an increased risk of SIPE among triathletes who wore wetsuits, in their unadjusted univariate regression analysis (OR 2.73, 95% CI 1.33 to 5.63, *p*=0.007). However, the authors found the association disappeared in their multivariate model once it controlled for gender, fish oil consumption, hypertension and course length. In their study of 165 cases of SIPE at an annual Swedish open water swimming event, Hårdstedt *et al.* (2021) reported that 98% had worn wetsuits.

Specificity

My multivariate analyses identified only two significant risk factors associated with SIPE (wetsuit use and asthma), which suggests the specificity criterion was met.

Temporality

We can say the temporality criterion was satisfied since it is clear that the swimmers put on wetsuits prior to swimming and not vice versa.

Biological gradient

A biological gradient was demonstrated by the linear trend in effect size from no wetsuit to non-tight wetsuit to tight wetsuit.

Plausibility and coherence

There is some evidence that wetsuits may have cardiovascular and respiratory effects. For example, tight-fittings wetsuits have been reported to increase mean arterial pressure, compared to no wetsuit (Prado *et al.* 2017). Another study showed that diving wetsuits decreased heart rate, cardiac output and right ventricular early diastolic filling, and increased peripheral vascular resistance (Marabotti et al., 2017). Castagna et al. (2013) found that the pressure exerted by diving wetsuits had a diuretic effect, reducing plasma volumes and increasing urine output, in dry conditions as well as during immersion. However, during immersion, the wetsuit pressure effect merged into the larger main effect of hydrostatic pressure. This supports the theory put forward by Carter and Koehle (2011) that a tight wetsuit may add to the compression effect of hydrostatic pressure on the body, which could lead to increased venous return and pulmonary artery pressures. This biological mechanism could help to explain why I found a strong association between wearing a tight wetsuit and SIPE in my study.

Experiment

I was unable to find any RCTs or natural experiments to provide compelling evidence of an association between wetsuit use and SIPE.

Analogy

I did not find any other similar exposures or risk factors that produced a similar outcome.

Overall, the application of Bradford Hill causal considerations indicated there was strong evidence for causality between tight wetsuit use and SIPE, with seven out of the nine Bradford Hill criteria fulfilled.

6.4.3.2 Asthma

I found that having ever had a diagnosis of asthma was a risk factor for SIPE. I used the Bradford Hill criteria (Hill 1965) to explore causality between asthma and SIPE.

Strength of the association

The association between asthma and SIPE was weak to moderate according to threshold values set by Chen, Cohen and Chen (2010).

Consistency

There is some evidence of a link between asthma and SIPE. For example, asthma was the most common comorbidity identified by Hårdstedt *et al.* (2021) in their study of competitors of an annual Swedish open water swimming event. They reported an asthma prevalence of 18% out of 165 cases, which is much higher than the 8.3% reported for the Swedish population aged 16–75 in 2009 (Lötvall *et al.* 2009). A follow-up study of SIPE cases identified at this event found that having asthma increased the likelihood of SIPE symptom durations of two days and a recurrence within 30 months (Kristiansson *et al.* 2023).

Specificity

There was a risk that the SOB experienced by asthmatic respondents may have been caused by asthma itself, therefore asthma did not meet the specificity criterion. If I had asked respondents about inhaler use during their SOB episode and whether it reduced or improved their symptoms, it is possible the specificity criterion could have been met.

Temporality

It was not possible to demonstrate temporality because I did not collect information on the asthma diagnosis date so did not know if this occurred before the first episode of SIPE.

Biological gradient

A biological gradient was not present because the asthma diagnosis variable was binary and indicated only the presence or absence of the disease.

Plausibility and coherence

There is some evidence that asthma is associated with the thickening of the wall of pulmonary blood vessels. Mostaço-Guidolin, Yang and Hackett (2021) compared the inner lining (tunica intima) of pulmonary arteries and veins in the lungs of 13 asthmatic patients with 12 healthy controls and found it was thicker in patients with asthma, even when controlling for age, sex and fatal disease, and collagen deposition was greater. Saetta *et al.* (1991) carried out an autopsy of six patients who died from an asthma attack and six control subjects and found the asthmatic subjects had an increase in the thickness of the walls of muscular pulmonary arteries adjacent to airways, compared to controls. This increased thickness of pulmonary artery walls could potentially increase pulmonary vascular resistance, leading to increased pulmonary artery pressures. The mechanism for this pulmonary vascular remodelling is not yet clear, although a similar phenomenon is known to occur in patients with other airway inflammatory diseases such as COPD.

Experiment

No experimental evidence for the association between asthma and SIPE was identified.

Analogy

Evidence for high altitude pulmonary oedema (HAPE) suggests that hypoxic pulmonary vasoconstriction leads to increased pulmonary artery pressures, which in some individuals can lead to the development of pulmonary oedema (Dehnert *et al.* 2007).

Overall, I found a small amount of evidence to support a causal association between asthma and SIPE, however there were five causal criteria that were not fulfilled i.e. consistency, specificity, temporality, biological gradient and experiment.

6.4.3.3 Other findings

My analysis showed that people diagnosed with a nasal allergy were at an increased risk of SIPE, however, this association was explained by asthma diagnosis. Asthma and nasal allergies affect the same airway and are both considered to be part of the atopic spectrum. It has been reported that approximately 15–38% of people with a nasal allergy also have asthma and 6–85% of people with asthma get nasal allergy symptoms (Brożek *et al.* 2017).

My results showed the risk of SIPE in women increased as BMI decreased, however, this effect was explained by wetsuit use being more common among females with a lower BMI. There was no association between SIPE and BMI in men, although this may have been due to the small number of male respondents in my sample (*n*=308) and therefore lack of statistical power. Alternatively, it may be that having a lower BMI is only a risk factor for SIPE in women. My results signalled a potential increased risk of SIPE among shorter men and women, however, these effects were not statistically significant. Misclassification may have been an issue since height and weight data were all self-reported.

I found that respondents who abstained from alcohol in the previous six months were at a higher risk of SIPE compared to those that consumed alcohol. This is most likely because of an unknown factor associated with being a non-drinker. For example, the "sick quitter" hypothesis might help to explain these findings. It was first proposed by Shaper, Wannamethee and Walker (1988) to describe the phenomenon whereby non-drinkers have poorer health than drinkers because the non-drinker category often includes former drinkers who gave up alcohol due to a diagnosed illness or long-term alcohol abuse, as well as lifelong abstainers. I did not find a significant association between smoking and SIPE.

My analysis showed an increased risk of SIPE when swimming in water temperatures of 12–23^{o}C , compared to <12^{o}C. However, further investigation revealed the water temperature effect was explained by the greater use of wetsuits in water ≥12^{o}C. This may be due to the greater tendency of triathletes/multisport athletes to swim in warmer water and to wear wetsuits for buoyancy and streamlining reasons, particularly during training and racing.

My results signalled a possible protective effect of antiplatelet drugs, although the association was not significant due to there being only two SIPE cases who took this type of medication. Previous studies have theorised that antiplatelet substances such aspirin or omega-3 fish oils may increase capillary permeability if pulmonary artery pressures are high (Miller, Calder-Becker and Modave 2010; Boussuges *et al.* 1999). However, a recent Cochrane Review concluded that omega-3 fatty acids EPA and DHA had a protective cardiovascular effect (Abdelhamid *et al.* 2020). This is thought to be partly due to their anti-inflammatory effects, which help to maintain the integrity of capillaries, therefore lessening the risk of a leak. In their multivariate analysis of data for triathletes, Miller, Calder-Becker and Modave (2010) did not adjust for age, which may help to explain the findings regarding fish oil, since research suggests fish oil users tend to be older than non-users (Li *et al.* 2020). I found no association between SIPE and taking hypertensive medication or female sex hormones.

The data showed signs of a potential increased risk of SIPE among multisport swimmers, although the results were not significant.

Unlike Miller, Calder-Becker and Modave (2010), I did not find an association between SIPE and having a diagnosis of hypertension. In their study of triathletes, Miller, Calder-Becker and Modave (2010) reported an adjusted odds ratio for SIPE of 5.38 (95% CI: 2.15–13.48, p<0.001) in triathletes with self-reported hypertension compared to those without, although they did not adjust for age in their analysis. In another study, Wilmshurst *et al.* (1989) found significantly higher blood pressure in a group of pulmonary oedema susceptible divers after exposure to cold and/or increased partial pressure of oxygen, compared to the control group. Miller, Calder-Becker and Modave (2010) suggested the increased risk of SIPE in hypertensive individuals may be due to the link between hypertension and diastolic dysfunction (stiffening of ventricles) which causes pulmonary artery pressures to increase. The absence of an association between hypertension and SIPE in this study may have been due to the very small number of SIPE cases that said they had high blood pressure (*n*=6), which limited the statistical power of the analyses. The proportion of respondents in my sample with hypertension (7%) was much lower than the England average for 2019-20 (14%) (NHS England 2020). Another reason why my results did not show hypertension to be a risk factor may be because many hypertensive respondents were aware of it and taking medication to control their blood pressure. There was also a risk of misclassification if some respondents were referring to a historical diagnosis that was no longer current, or if they were not aware they had hypertension. Therefore, it is possible that uncontrolled hypertension may still be a risk factor.

Having a heart condition was not a risk factor for SIPE, although only six of the SIPE cases had this type of diagnosis, so statistical power was very limited. In their literature review of 292 cases of SIPE, Peacher et al. (2015) reported that 50 (17.1%) had cardiac issues. Heart disease was also reported by Hårdstedt et al. (2021) as a comorbidity in a six SIPE cases (3.6%).

My literature search identified a study which reported Raynaud's syndrome in a SIPE susceptible individual (Wilmshurst et al., 1989), however, I found no such association in my analysis. This may have been due to the very small number of SIPE cases with this diagnosis (*n*=4), which limited statistical power. It is possible the number of cases with Raynaud's was higher since my results suggested 25% of cases had experienced symptoms that suggest they might have Raynaud's syndrome, although most had not been formally diagnosed. This is higher than the estimated UK prevalence figure of 0.5–21% according to NICE (2022). However, the high percentage is most likely due to the very loose definition of Raynaud's syndrome given in the questionnaire of "reduced blood flow to fingers and toes in response to cold", with no mention of important symptoms such as colour changes to the fingers, numbness and pain. Therefore, the true prevalence of Raynaud's among SIPE cases is likely to lower than 25%.

I did not find any indication that having a panic attack diagnosis was a risk factor for SIPE, although only six SIPE cases had this diagnosis so statistical power was very low.

In contrast to Miller, Calder-Becker and Modave (2010), I did not find an association between swimming distance and SIPE. However, similar to these authors, my results showed a strong correlation between wetsuit use and swimming distance, with wetsuit users much more likely to swim >1km compared to non-wetsuit users.

The frequency of outdoor swimming, and the months of the year in which respondents swam i.e. year round swimmers versus those who did not swim in the coldest months, were not associated with SIPE. This suggests that the amount of previous exposure to cold water or cold water habituation were not predictors of SIPE, or it may be due limitations in data collection i.e. misclassification due to recall bias or the definition of colder months as January to April.

My results signalled a potential reduced risk of SIPE among swimmers that had a drink before swimming, although this was not a significant association at $p<0.05$, and did not take into account the volume of liquid consumed or fluid intake during the swim. This result is in contrast to the findings of Weiler-Ravell et *al*. (1995) who put forward overhydration as a risk factor after eight military trainees suffered from SIPE after consuming five litres in the two hours before swimming. A recent paper reviewed evidence on the effect of hypohydration (a milder form of dehydration) on cardiovascular health and concluded that hypohydration impaired cutaneous vascular function, reduced endothelial function and affected the regulation of blood pressure during exercise (Watso and Farquhar 2019). This suggests the issue of hydration levels and SIPE risk may be worthy of further investigation.

6.4.3.4 Generalisability

My risk factor sample of outdoor swimmers was over two-thirds female and 96% White ethnicity. This was similar to the sample collected by Outdoor Swimmer magazine in their two *Attitudes to Outdoor Swimming* surveys conducted in 2020 and 2021. They found that 65% and 74% of respondents were female respectively (Outdoor Swimmer 2022; Outdoor Swimmer 2021), and 96-98% were from a White background (Outdoor Swimmer 2022). However, it is possible the higher proportion of female respondents in these surveys may be due to gender differences in online survey participation, with women far more likely to respond than men (Becker 2022). Over 60% of my sample were aged between 40 and 59 compared to 65% of the *Attitudes to Outdoor Swimming survey* respondents in 2020 (Outdoor Swimmer 2021). Wetsuits were worn by 47% of my survey respondents (most of whom completed the survey between February and April), which was similar to the figure of 50% reported by Outdoor Swimmer magazine for swimmers in the winter months. I found that men were much more likely to wear a wetsuit compared to women (66% versus 41% respectively). Again, this was comparable to the 64% of male and 44% of female respondents to the 2020 Outdoor Swimmer survey who said they wore a wetsuit during winter swimming.

My sample was very heterogeneous, ranging from non-competitive recreational swimmers to competitive endurance athletes, so therefore will have incorporated a wide variety of body types, swimming environments, and behaviours. This means the study may be less generalizable since it is not clear what type of swimmer the observed effects may be applicable to.

6.5 Conclusions

My risk factor study provides strong evidence for a causal association between wearing a wetsuit (particularly a tight wetsuit) and SIPE. These are important findings that should be used to inform guidance for outdoor swimmers when purchasing or hiring a wetsuit. My findings also showed that having an asthma diagnosis was associated with SIPE, although evidence for a causal association was limited and it is possible that symptoms of an asthma attack may be difficult to differentiate from

SIPE in some instances. Asking respondents additional questions about inhaler use and whether it reduced or improved their SOB symptoms during the episode might have helped to improve the specificity of the SIPE case definition and reduce the risk of mistaking asthma symptoms for SIPE. Further studies that replicate these findings and explore other potential risk factors for SIPE, whilst controlling for confounding factors, are needed. Research into the cardiorespiratory effects of wearing tight wetsuits would also be helpful to understand the physiological mechanisms involved.

Chapter 7: SIPE case series

7.1 Introduction

The information presented in this chapter provides richer data than what I have previously presented in this thesis, about a number of aspects of SIPE. This includes the characteristics of SIPE episodes reported by individuals, such as associated symptoms, perceived causal attribution, medical attention received, and the number of similar episodes experienced. This chapter also includes a detailed description of the experiences of three outdoor swimmers before, during and after their reported SIPE events. All data were previously collected through the surveys and questionnaire testing I conducted.

Two review articles presented details of symptoms associated with SIPE events reported in published studies (Grünig *et al.* 2017; Hohmann, Glatt and Tetsworth 2018), however, most of the studies that were reviewed used clinical examinations to identify SIPE cases. This case series study includes cases that did not see a clinician, as well as those that did, which may help to develop a more comprehensive understanding of the range of symptoms associated with SIPE at varying levels of severity. This information could lead to earlier recognition of the condition and more timely interventions, resulting in a reduced risk of harm for affected swimmers.

Some swimmers that have experienced SIPE may attribute their symptoms to other causes, possibly due a lack of awareness of the condition, or comorbidities such as asthma or hay fever that sometimes cause SOB. Investigating the perceived cause to which cases attributed their SOB can help to identify individuals who are not aware they may have suffered SIPE, so they can be informed about the condition, the risk of a recurrence and potential preventative measures they can take. This type of information could also be used to help develop a standardised case definition for SIPE with high specificity to ensure better differentiation between SIPE and other causes of SOB that may present similarly.

As discussed above, the majority of published studies into SIPE identified cases from individuals that received medical attention for their symptoms. Therefore, individuals who did not access medical care at the time of their SIPE event would have been excluded from the studies. This study includes cases that were detected through a questionnaire survey of outdoor swimmers, so includes individuals who did not get any medical help for their symptoms. My questionnaires did not ask participants to rate the level of severity of their symptoms, therefore, in the absence of these data, details of any medical attention received may provide a useful proxy measure of this. However, in the absence of a validated measure of severity of symptoms, it remains a subjective concept. Information on the type of medical care that was given may also help with developing best practice guidance for healthcare professionals, so they are able to provide timely and effective care to swimmers suffering from SIPE.

My systematic review found that recurrences of SIPE were common, although the heterogeneity of study designs made it difficult to quantify this. It concluded that further research is needed to better understand the risk of recurrence for affected swimmers. My questionnaires collected information about the number of similar episodes of SOB cases had experienced to indicate which episodes were recurrences of previous SIPE events.

Qualitative data is often used alongside quantitative data to provide more context and deeper insights. Three of the individuals included in this case series took part in cognitive interviews as part of the questionnaire testing process (see section 4.2.2.3). These cases gave a detailed account of what happened before, during and after their SIPE episode. In this case series, I have summarised this information to try to capture the complexity of their experiences, symptoms and outcomes, that can't be fully explained by the quantitative data I have presented.

Case series studies provide a useful way to present valuable information that helps to understand relatively recently recognised and poorly understood conditions (Torres-Duque, Patino and Ferreira 2020). For example, shortly after the outbreak of COVID-19 in China, researchers published a detailed case series of 41 patients who were hospitalised with the virus, 15% of whom died during the study period (Huang *et al.* 2020). The article was the first published account of COVID-19 and helped clinicians from around the world understand better how to diagnose and treat the condition.

The objectives of this study were to investigate the characteristics of SIPE episodes, including associated symptoms, attribution of symptoms by cases, medical care received, previous episodes experienced, and details of the individual experiences of three cases.

The research questions were as follows:

1. What further symptoms not reported in my previously presented studies did the participants report?
2. What did the people who I considered to have experienced SIPE think their symptoms were due to?
3. What proportion of reported SIPE episodes represent recurrences?
4. What proportion of cases received medical attention and what were the specific details of this?
5. What are the perceptions and experiences of individuals regarding the events leading up to, during, and following an episode of SIPE?

7.2 Data collection methods

7.2.1 Participants

Participants were defined as respondents of Hever Castle pre and post-race surveys and the outdoor swimming survey, and participants of online questionnaire tests and cognitive interviews which took place during the questionnaire development phase, who met the following case definition of SIPE:

SOB that was reported by the swimmer as being out of proportion to the effort being put in, and EITHER:

a) A doctor has told them that it was due to pulmonary oedema or SIPE; OR

b) *They do not believe it was caused by inhaling water AND it did not occur immediately on entering the water*

Previous chapters have set out details of the Hever Castle Triathlon and outdoor swimming surveys (chapter 5), and questionnaire testing (chapter 4).

7.2.2 Variables

The variables of interest included the following:

1. Symptoms of SIPE
2. Perceived attribution of symptoms
3. Details of medical attention received for SIPE i.e. timing, type and location of medical care, length of stay in hospital
4. Number of similar episodes experienced

Details of the individual questionnaire items used to gather the above information are given below.

7.2.2.1 Symptoms of SIPE

The questionnaires used in the outdoor swimming survey and Hever Castle Triathlon pre and post-race surveys asked if respondents had experienced any of the following symptoms at the time of their most recent episode of SOB:

- Wheezing or whistling in the chest
- Crackling sound in the chest
- An unexplained cough
- Coughing up phlegm, froth or fluid
- A feeling of tightness in your chest
- Other: Please specify (free text)
- No other symptoms

Questionnaire testing respondents and cognitive interviewees were asked a similar question, but were given the following slightly different response options:

- Whistling or crackling sound in the chest
- A cough not related to a cold or other respiratory infection
- Coughing up phlegm or fluid
- A feeling of tightness in your chest
- Other: Please specify (free text)

7.2.2.2 Perceived attribution of symptoms

Outdoor swimming survey and Hever Castle Triathlon survey respondents were asked whether they thought their SOB was due to any of the following:

- Panic attack
- Smoking
- Cold shock response
- Allergies such as hay fever
- Asthma
- COPD
- Chronic bronchitis
- Emphysema
- Heart condition
- Pulmonary embolism
- Pulmonary oedema or SIPE
- Other reasons (free text)

Questionnaire testing and cognitive interview participants were given a shorter list of response options:

- Panic attack

- Smoking
- A nasal allergy i.e. hay fever
- Asthma (including exercise-induced)
- Pulmonary oedema
- Other reason: please specify (free text)

7.2.2.3 Medical attention

The questionnaires asked whether cases had received any medical attention for their SOB. Those that said yes were asked about the timing of medical attention following the onset of SOB i.e. immediately, <2 hours, 2–11 hours, 12–24 or >24 hours. Details about the type of medical treatment received were provided by cases using the following response options: observation only, diuretics, oxygen, inhaler, other (free text), and not sure. Cases were also asked to specify where they had received medical attention i.e. on site, ambulance, hospital, other healthcare facility i.e. clinic, GP surgery etc. Cases that said they had attended hospital were also asked where in the hospital they were seen i.e. A&E, an outpatient clinic or a hospital ward, as well as how long they stayed in hospital i.e. less than a day (no overnight stay), 1, 2 or ≥3 nights.

7.2.2.4 Number of similar episodes experienced by cases

Cases were asked to state the total number of similar episodes of SOB they had experienced, using the response options of 1, 2, 3, 4, and 5 or more.

7.2.3 Qualitative data

Cognitive interviews were conducted as part of the questionnaire development and testing process (see section 4.2.2.3). During these interviews, three cases provided a detailed account of the events leading up, during and after their episode of SOB. I extracted this information from interview transcripts and condensed it into brief summaries.

7.3 Results

7.3.1 Participants

7.3.1.1Methods of recruitment

A total of 107 SIPE cases were identified in the course of data collection for this thesis. Recruitment methods for cases are shown in Table 30 in chapter 6. The majority (87%) of cases were respondents of the outdoor swimming survey. Another 10 cases were participants of online questionnaire tests, three of whom also took part in cognitive interviews that formed part of the questionnaire testing and validation process. An additional four cases had taken part in triathlon (*n*=3) or aquathlon (*n*=1) races at Hever Castle Triathlon and completed the pre-race (*n*=1) or post-race survey (*n*=3).

All data collection was carried out through online questionnaires, apart from the three cognitive interviews which took place in-person (*n*=1) or by telephone (*n*=2). Two Hever Castle Triathlon finishers completed the post-race survey shortly after finishing the race using a tablet at the event.

7.3.1.2 Demographics

Demographic details of SIPE cases included in this study are provided in Table 31 in chapter 6. The majority of SIPE cases (63%) were aged between 40 and 59. Almost two thirds were female and only one case was from a minority ethnic group. Just under half of cases resided in London or the South, with the remainder spread across Britain, apart from one who lived abroad.

7.3.2 Symptoms associated with SIPE

Thirty-seven participants (35%) said they did not experience any symptoms other than SOB at the time of their SIPE episode. Table 47 includes details of additional symptoms reported by the other 70 cases. The most commonly reported symptom was a feeling of tightness in the chest, which was reported by 58% of cases who had additional symptoms. Over a third of cases who had other symptoms said they had been wheezing or had a whistling or crackling sound in the chest, and 24% of cases had an unexplained cough. Only 10 cases (14.3%) said they had coughed up phlegm, froth or fluid, of whom five specified the colour (pink, red or bloodstained (*n*=3), brown (*n*=1), white (*n*=1)).

Nine cases said they had other types of symptoms, such as panic/anxiety (*n*=3), dizziness (*n*=2), extreme fatigue (*n*=1), a tight neck (*n*=1), disorientation (*n*=1), and nausea (*n*=1). One individual recalled their vision turning to black and white during the episode.

Table 47: Symptoms experienced in addition to SOB during SIPE episode

Symptoms	***N* (%)**
A feeling of tightness in the chest	
Yes	41 (58.6)
No	29 (41.4)
Data missing	0 (0.0)
Wheezing or whistling/crackling sound in chest	
Yes	26 (37.1)
No	38 (54.3)
Data missing	6 (8.6)
Unexplained cough	
Yes	17 (24.3)
No	53 (75.7)
Data missing	0 (0.0)
Coughed up sputum (phlegm, froth or fluid)	
Yes	10 (14.3)
No	60 (85.7)
Data missing	0 (0.0)
Other symptoms	
Yes	9 (12.9)
No	61 (87.1)
Data missing	0 (0.0)

7.3.3 Perceived attribution of symptoms

Figure 8 below shows the perceived attribution of swimming related SOB symptoms reported by cases. Thirty-nine cases (36.4%) attributed their SOB to multiple reasons. Only nine cases (8.4%) thought they had experienced SIPE (seven of whom had been diagnosed with SIPE). Cold water or low air temperature was the most common attribution cited, accounting for 44% of cases. The next most frequently suggested causes included either asthma/nasal allergies or psychological factors, each accounting for around 22% of cases.

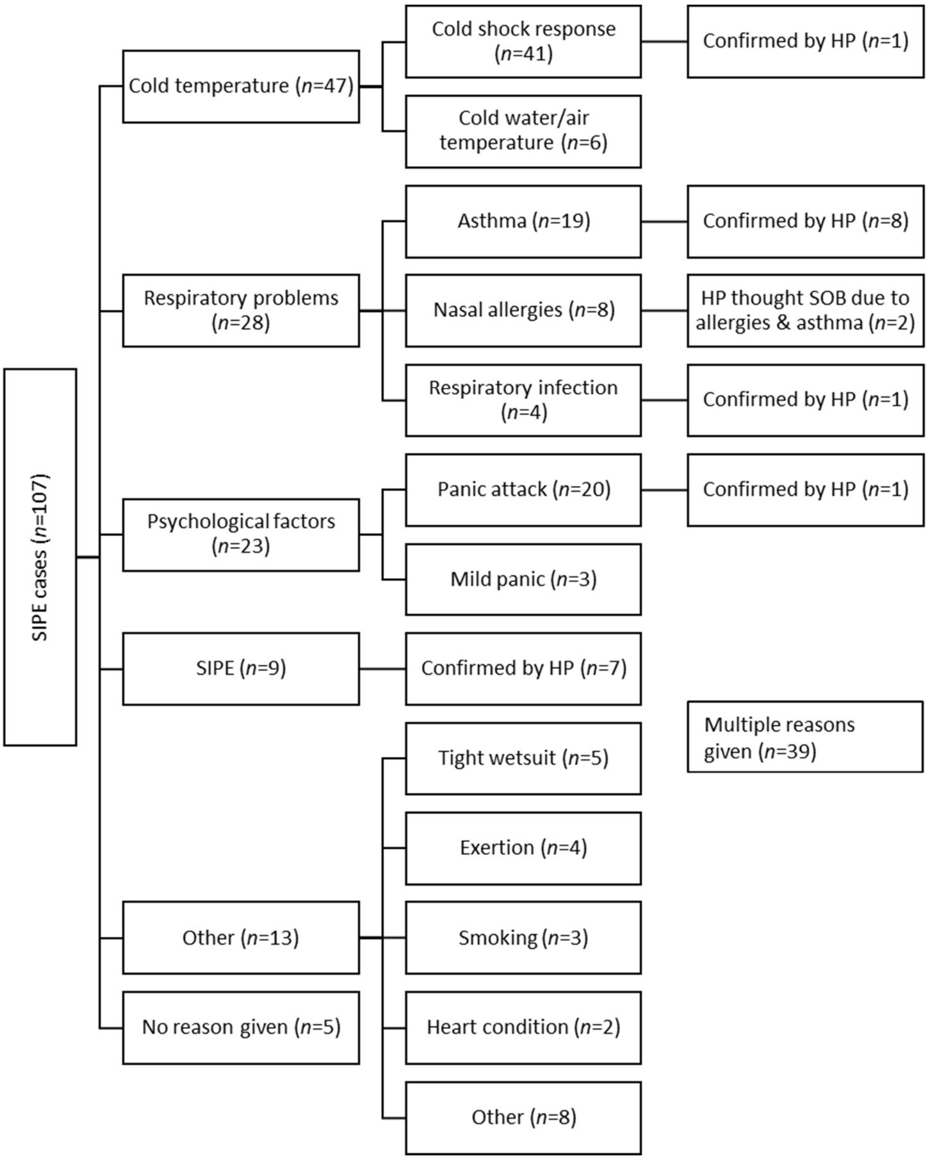

Figure 8: Attribution of swimming related SOB symptoms by cases. SOB = shortness of breath

7.3.4 Medical attention

Only seven cases (6.5%) said they received medical attention due to their most recent episode of SIPE; two cases reported seeing a doctor at the site where they were swimming, three cases were transferred to A&E and admitted to hospital, one case underwent a chest x-ray at hospital (unknown referrer), and two visited their GP later on, one of whom was Case B, a cognitive interviewee (see Table 49 and section 7.3.6.2 for further details). The three cases that were admitted to hospital stayed for at least 3 days. They were all taking part in long distance sea swims (at least two of whom had been attempting to cross the English Channel). One of the cross Channel swimmers was cognitive interviewee Case A who reported being treated with oxygen and diuretics, was catheterised and underwent a number of diagnostic tests (see Table 49 and section 7.3.6 for further details). No details of hospital treatment were provided by the two other cases, apart from glucose shots for one and the "draining of fluid" for the other. Two cases saw their GP; one (Case B) attended because of vomiting and an acute headache that had developed two days after her SIPE episode. The other visited the GP at an unspecified time after the episode, but reported having received no medical treatment.

7.3.5 Previous SIPE episodes

Table 48 shows that 71% of cases (*n*=76) had experienced more than one episode of this type of SOB. A fifth of cases had experienced similar symptoms on five or more occasions.

Table 48: Number of SIPE episodes experienced by cases

Number of episodes	***N* (%)**
1	25 (23.4)
2	29 (27.1)
3	19 (17.8)
4	6 (5.6)
≥5	22 (20.6)
Data missing	6 (5.6)

Table 49: Details of medical attention received by SIPE cases

Sex	Age	Type of open water swim	Estimated water temperature (°C)	Wetsuit use	Timing of SOB onset after start of swim	Additional symptoms experienced	When medical treatment received	Reported details of medical treatment	Length of hospital stay
Male (Case A)	44	Cross channel swim	17°C	No wetsuit	11 hours	Tight chest, wheeze, coughed up sputum. Reported having aspirated water. Lower abdominal pain possibly due to urinary retention	Straight away. Dragged from the sea in a semi-conscious state after 12.5 hours of swimming	First aid given by nurse on boat, then airlifted to A&E. Given oxygen in air ambulance. Treated for hypothermia at hospital, given oxygen and diuretics, and catheterised. Admitted to hospital ward. Blood tests, chest x-ray, ECG, echocardiogram and angiogram undertaken. Blood tests showed high levels of troponin.	4 days
Male	40–49	Cross channel swim	15.5°C	No wetsuit	19.5 hours	Tight chest	Straight away	Admitted to hospital ward (assuming via A&E). No details of treatment other than “drained of fluid”	6 days
Female	40–49	Long distance sea swim	17.5°C	No wetsuit	Several hours into swim (exact time not specified)	Tight chest, whistling/crackling in chest, unexplained cough, coughing up sputum. Vision went to black and white, very disorientated after 4 hours	Straight away. Pulled from sea after 5 hours of swimming	Treated onsite and transferred by ambulance to A&E. Two glucose shots for extremely low blood sugar. Admitted to hospital ward and initially diagnosed with having had a heart attack	≥3 days
Female	60–69	500–1000m (unspecified water body)	12°C	Wetsuit	Not specified	Whistling/crackling in chest, unexplained cough, coughing up pink froth	Not specified	X-ray at hospital (unclear who made referral). Initially diagnosed with an infection and given antibiotics	N/A
Female	50–59	>3000m (unspecified water body)	15°C	No wetsuit	Not specified	Whistling/crackling in chest, unexplained cough	Not specified	Observation onsite. Also treated in another unspecified healthcare facility	N/A
Female (Case B)	44	750m race in lake	12–15°C	Wetsuit	Almost straight away	Crackling in chest, unexplained cough, dizziness, coughing up sputum	2 days later	Went to GP after becoming ill with vomiting and severe headache. Given antibiotics for inflammation in the head	N/A
Female	50–59	<500m	20°C	No wetsuit	Not specified	Tight chest, coughing up sputum	Not straight away	Went to GP. No treatment given	N/A

A&E = Accident and Emergency; ECG = electrocardiogram; GP = General Practitioner. Note: Data for cases A and B were collected during cognitive interviews as part of the questionnaire testing and validation process. All other data were collected from the outdoor swimming survey.

7.3.6 Qualitative interviews

7.3.6.1 Case A: Cross-Channel Swimmer

A White male aged 44 years from the south of England began to feel breathless eleven hours into a swim across the English Channel from Dover in 2016. The man was not wearing a wetsuit and water temperature was 17^{o}C. He felt tightness in the chest, thought he had aspirated some water, and began wheezing and coughing up fluid. He reported having lower abdominal pain which he attributed to urinary retention. The man continued swimming, but was dragged from the sea in a semi-conscious state an hour and a half later and given first aid on the support boat by a qualified nurse. He was transferred to hospital by air ambulance.

The man weighed 90kg and was 1.8m tall. Medical history included diagnosed hypertension and high cholesterol, for which he had been prescribed 5mg Lisinopril and 40mg Atorvastatin. He thought he may have previously experienced mild Raynaud's syndrome during winter swimming after a few hours in the water, due to his hands and feet going "dead" for a bit, before coming back to life swiftly. However, he had not had a formal diagnosis. On the day of the channel crossing, the swimmer had consumed 400ml of fluid in the hour before swimming and had completed a short swim to the starting point. He drank 400ml fluid every 45 minutes for the first six hours and then every 30 minutes thereafter. He did not report feeling anxious or nervous at any point during the swim. He said he had quit smoking 25–30 years previously and reported typically consuming around three alcoholic drinks per week

Upon arrival at the boat, paramedics immediately administered oxygen. At hospital the man said he was treated for hypothermia and given more oxygen as well as diuretics. A catheter was inserted and he eliminated several litres of fluid in a 45 minute period. He said that blood tests showed high levels of troponin and further diagnostic tests were undertaken, including a chest x-ray, ECG, echocardiogram and angiogram. The man was admitted for four nights and diagnosed with non-cardiogenic pulmonary oedema. Two months after discharge, he had a follow-up GP appointment and was given an increased dose of Lisinopril (15mg) to control blood pressure.

The swimmer reported having experienced a similar type of SOB previously during a six-hour training swim. He described the symptoms as “only a very slight, rattling chest”. He did not seek any medical help at the time and felt well the next day.

7.3.6.2 Case B: Triathlete in Welsh lake race

A White 44 year old female took part in a three mile swimming race across Bala Lake, Wales in July 2014. An hour into the swim she began experiencing SOB, coughing, a whistling/crackling sound in the chest, tightness in the chest, dizziness, and was coughing up phlegm. She did not think she had aspirated water. She was struggling but continued to swim very slowly until she finished the race at just over three hours. She was observed at the medical tent and told to go to A&E but went home instead. She did not receive any medical treatment until two days later when she saw a GP due to becoming very ill with continual vomiting and a severe headache.

The woman was 170cm tall and weighed 57kg. She had no medical diagnoses although she suspected she may have Raynaud’s syndrome. She did not take any regular medication or dietary supplements. The swimmer had consumed less than half a bottle of a sports drink before the race and was able to drink when necessary during the swim. She estimated the water temperature to have been 12–15^{o}C. The woman wore a wetsuit and swam at a moderate pace. She reported no feelings of anxiety or nervousness during the race. She had never been a smoker and reported consuming alcohol around twice a month during race season.

The woman said that the GP diagnosed an infection in the head and prescribed antibiotics. The GP thought the symptoms experienced during the race were due to pulmonary oedema. The woman swam again at the same lake a few months later at a sprint triathlon. The swim distance was 750m and the water temperature was around 12–15^{o}C. Case B wore a wetsuit and consumed less than half a bottle of sports drink before the race. She swam at a strenuous effort level and began to experience SOB almost straight away, with associated coughing, crackling and dizziness, although the symptoms did not become very severe due to the short swim distance (750m). The woman finished her swim and was able to complete the triathlon. Two days later she became very ill with vomiting and a severe headache, similar to before. She saw her GP who gave her antibiotics for a suspected inflammation in the head. She said the GP thought she had experienced pulmonary oedema again. The woman did not swim in open water again.

7.3.5.1 Case C: Triathlete in Kent lake race

A White male aged 52 years experienced SOB whilst swimming a 1km lake race in Lydd, Kent in September 2018. Other symptoms included a cough, feeling of tightness in the chest and coughing up phlegm/fluid. He completed the race, but had to swim using a very strenuous slow breaststroke. He did not consult a doctor after the race because he was already receiving treatment for dilated cardiomyopathy, so had attributed the SOB to that. This treatment had involved a number of diagnostic tests including a chest x-ray, echocardiogram, MRI and angiogram. The man had been taking a number of medications (Entresto, Eplerenone, Apixaban, Bisoprolol Fumate). He had never been diagnosed with asthma, but suspected he may suffer from exercise-induced asthma. The water temperature was 17^{o}C and the swimmer wore a wetsuit. He drank half a bottle of fluid in the hour prior to swimming and did a short swim in the water before the race started. He did not feel anxious or nervous during the swim. He was a non-smoker and reported drinking 3–4 alcoholic drinks two to four times per month. He said he had experienced similar symptoms during outdoor swimming three times previously, the first time being in his late forties.

7.4 Discussion

7.4.1 Key results

This case series reports the characteristics of SIPE episodes experienced by 107 individuals, including associated symptoms, perceived causal attribution, medical care received, and previous similar episodes. Over a third of cases said they had no symptoms other than SOB. In descending order, the most common associated symptoms reported by the remaining cases were a tight chest, wheezing or whistling/crackling sound in the chest, and an unexplained cough. Coughing up sputum was reported by only 9% of swimmers. Most cases did not attribute their SOB to SIPE unless they had been diagnosed with SIPE, citing other perceived causes such as cold shock, asthma, nasal allergies, respiratory infections, panic, tight wetsuit or exertion. Only seven cases reported receiving any medical attention for their SOB and related symptoms. Three of them reported seeing a medical team at the site where they were swimming, three were transferred to A&E, one underwent a chest x-ray at hospital and two reported visiting their GP. The three cases who attended A&E were admitted to hospital for at least three days, all of whom had been several hours into a long distance sea swim and had not been wearing a wetsuit. Seventy percent of cases said they had experienced previous similar episodes of SOB, and over a fifth said it had happened on at least four previous occasions.

7.4.2 Strengths and limitations

To my knowledge, this study is one of the largest case series that reports primary data collected from swimmers who have experienced symptoms compatible with SIPE. It presents important supplementary information about the characteristics of SIPE episodes, not already discussed in previous chapters. The study participants consisted of a large heterogeneous group of outdoor swimmers with symptoms varying in severity, from recreational swimmers who suffered from minor SOB, to cross channel swimmers who were pulled out of the English Channel and airlifted to hospital.

It is possible the SIPE case definition I used to identify cases was flawed and lack specificity, resulting in the inclusion of false positives in this case series. The case definition may also have lacked sensitivity due to the exclusion of respondents who aspirated water, potentially leading to false negatives. My questionnaire validation and testing process, however, indicated the SIPE case ascertainment questions were reasonably sensitive and specific (although minor changes were made to the wording following testing) (see chapter 4).

Some questionnaire items could have been refined further to improve clarity. For example, the question that collected information on perceived attribution of symptoms did not include a clear reference period i.e. it could have been interpreted as either what the respondent thought at the time of the incident or what the respondent thought in hindsight. There were also issues with consistency of responses, with similar questions being answered in a contradictory fashion.

There are a number of pieces of information that were not collected in the survey instrument that would have provided useful contextual data. For example, the type of water body in which cases were swimming at the time of their SIPE event and environmental conditions i.e. windy, rough/choppy conditions with strong currents vs flat, calm water. I also did not collect any information on the time taken to recover from SIPE or ask respondents to rate their level of breathlessness. Another key area of interest that I did not include in this study was the long term effects of SIPE on the cardiorespiratory system, such as residual symptoms.

7.4.3 Discussion of the relevant literature

7.4.3.1 Symptoms of SIPE

Over a third of cases in this study reported having had no symptoms other than SOB during their suspected SIPE episode. This is in contrast to many previous studies where the SIPE cases were identified on the basis of them having suffered from SOB along with other symptoms, such as cough, wheeze, whistling/crackling in chest, or coughing up sputum.

Among the 65% of cases who experienced additional symptoms, tightness in the chest was the most commonly reported. This runs contrary to two review articles that found that only 8% and 2% of cases respectively reported chest tightness or chest pain during SIPE (Hohmann, Glatt and Tetsworth 2018; Grünig *et al.* 2017). In their study at an annual open water swimming race in Sweden, Hårdstedt *et al.* (2020) found that only 3 of the 102 participants who had SIPE confirmed by a lung ultrasound scan (LUS), reported chest pain.

Other symptoms such as wheezing, or a whistling or a crackling sound in the chest, unexplained cough, or coughing up sputum were less prevalent in this sample compared to previous studies. For example, around a quarter of cases in this series experienced wheeze or a whistling/crackling sound in the chest, whereas Grünig *et al.* (2017) reported that 100% of the 19 that underwent lung auscultation showed wheeze or crackles (although only one had these as initial symptoms). Hårdstedt *et al.* (2020) also reported a higher incidence of crackles (84%) among 102 patients with LUS-verified pulmonary oedema who underwent lung auscultation. An unexplained cough was reported by 14% of cases in this study compared to the 71% and 56% reported to by Grünig *et al.* (2017) and Hohmann, Glatt and Tetsworth (2018) respectively. The 9% who reported coughing up sputum was also much lower than incidence of froth reported in review papers of 51% of cases (Hohmann, Glatt and Tetsworth 2018) and haemoptysis in 68% and 33% of cases (Grünig *et al.*, 2017; Hohmann, Glatt and Tetsworth, 2018 respectively). Hårdstedt *et al.* (2020) reported that 31% of LUS-verified pulmonary oedema patients presented with sputum and 3% with haemoptysis.

The reason for the lower incidence of these symptoms compared to published literature may be because of the way in which cases were identified in my study. Rather than restricting data collection to swimmers who sought medical help like in many previous studies, my sample included those who suffered milder SOB that resolved over time so there was no need to see a clinician. This means my study was able to detect much milder cases of SIPE, in addition to more severe cases who received medical attention.

7.4.3.2 Perceived attribution of symptoms

Less than 10% of cases in this study attributed their symptoms to SIPE, most of whom had been diagnosed with SIPE. Instead, the majority of cases suspected the cause to be cold shock, asthma or nasal allergies. This suggests that awareness of SIPE among swimmers may be limited or that cold shock, asthma or nasal allergy symptoms may be difficult to differentiate from SIPE symptoms. There is also the possibility that asthma may be a risk factor for SIPE, as suggested in my risk factor study in chapter 6, although there was only a small amount of evidence to support a causal association. Two studies of competitors that presented with SOB to the medical team at a Swedish open water swimming event, also identified a possible link between asthma and SIPE. For example, Hårdstedt *et al.* (2021) found a higher than expected prevalence of asthma among SIPE cases and Kristiansson *et al.* (2023) reported a longer symptom duration and higher rate of recurrence among cases that had asthma compared to those that didn't.

7.4.3.3 Medical attention

The vast majority of cases (94%) did not receive any medical attention for their SIPE symptoms. These results, along with the low prevalence of more severe symptoms such as wheeze, whistling/crackling in the chest, cough and sputum, suggest that these individuals most likely experienced milder episodes of SIPE. This is comparable to the findings of Shupak *et al.* (2000) who surveyed military trainees taking part in swimming trials and reported that 21 of the 29 SIPE episodes detected (72%) were classed as mild episodes. Given that the majority of studies included in my systematic review identified SIPE cases from swimmers that sought medical attention, these findings highlight the need for more studies to include participants who experienced milder symptoms of SIPE, to more accurately reflect the population of affected swimmers.

Only three cases said they had been admitted to hospital after their SIPE episode, which suggests that admissions to hospital are not a common occurrence. This is consistent with the findings of Volk *et al.* (2021), Kristiansson *et al.* (2023) and Sebreros *et al.* (2023) who reported hospitalisations in 2%, 7%, and 4% of SIPE cases respectively. The three cases in my study that had been admitted to hospital were all cross Channel/long distance sea swimmers in their forties who had been swimming for at least five hours when they were pulled out of the sea. They had not been wearing wetsuits. One of these swimmers reported consuming a large volume of fluid over eleven hours of swimming, whilst also having difficulty urinating. It is not clear exactly why these swimmers experienced SIPE even though they were not wearing wetsuits, however, possible explanations could be potentially greater increases in PAP over time during hours of sustained swimming due to the combined effects of peripheral vasoconstriction, hydrostatic compression and prolonged exercise.

7.4.3.4 Previous SIPE episodes

Over 70% of cases said they had experienced similar episodes of SOB previously. This is much higher than the figures reported by Shupak *et al.* (2000) and Braman Eriksson, Annsberg and Hardstedt (2017). Shupak *et al.* (2000) found that 31% of 29 SIPE episodes experienced by military trainees were recurrences of observed episodes. In a larger study of nearly 14,000 outdoor swimming race competitors, Braman Eriksson, Annsberg and Hardstedt (2017) reported that 20 out of the 69 identified SIPE cases (29%) had previously experienced respiratory symptoms during open water swimming. My findings suggest that recurrences might be more common than previously thought, however, the limitations of my study design meant that the previous episodes of SIPE that were reported did not occur within the study period.

7.5 Conclusions

This case series reports data from a large heterogeneous sample of outdoor swimmers that suffered symptoms suggestive of SIPE. The following provides a summary of the key findings of this study:

1. Many people do not experience any symptoms other than SOB during their episode of SIPE. This has important implications for how we diagnose SIPE in clinical practice and for the way in which researchers identify cases of SIPE. We need to ensure that diagnostic criteria and SIPE case definitions are not too strict and do not exclude cases whose symptoms were limited to SOB.

2. Recurrence of SIPE is more common than previously thought. Rather than treating SIPE as a one-off event, it is important that affected swimmers are made aware they are more at risk

of having an episode during outdoor swimming, so they can take precautionary measures. These may include avoiding tight fitting wetsuits, getting a medical checkup to identify any undiagnosed conditions and following general water safety advice.

3. Tightness in the chest during an episode of SIPE may be more common than previously thought. This is important information that may help swimmers, race organisers and healthcare professionals to recognise the condition earlier and take appropriate action to reduce the risk of harm.

4. SIPE symptoms may be difficult to differentiate from other causes of SOB such as cold shock, asthma, or nasal allergies. This highlights the importance of developing a standardised case definition or diagnostic criteria with high specificity, so that cases of SIPE can be identified more accurately.

5. Only a small proportion of cases seek medical care for their SIPE symptoms. Research studies should therefore include participants that suffered milder episodes of SIPE to ensure the findings are applicable to the wider population of affected outdoor swimmers.

Chapter 8: Conclusions

8.1 Introduction

This chapter will review the key findings of my research with respect to the research questions, and consider its strengths and limitations. It will then make suggestions for future research and discuss the implications for policy and practice. The chapter will conclude with some personal reflections.

8.2 Returning to the research questions

In the following sections, I summarise the findings of my studies in relation to the research questions that I set out in the Introduction chapter.

8.2.1 What is the prevalence of having experienced SIPE?

My prevalence study used a sample of 1,078 responses to four surveys of open water swimmers in the UK. Lifetime prevalence estimates of SIPE ranged from 0.1% (case definition: SOB and coughing up pink, red or blood sputum, not immediately on entering the water, in absence of water aspiration) to 22.2% (case definition: SOB immediately, during or straight after swimming) of outdoor swimmers. I chose to base my research on the following case definition to try to exclude individuals that had experienced cold shock or had aspirated water: "*Shortness of breath that was out of proportion to the effort being put in, not immediately, in the absence of water aspiration".* This produced a prevalence estimate of 9.0% of outdoor swimmers.

8.2.2 What is the incidence of SIPE?

My incidence study was based on a sample of 108 responses to a survey of triathlon event competitors that took part in races involving open water swimming. Depending on the case definition used, SIPE incidence ranged from 2.8% (case definition: SOB not immediately in absence of water aspiration) to 14.8% (case definition: SOB immediately, during or after swim) of race competitors.

8.2.3 What are the risk factors for SIPE?

I carried out a case control study using data from 980 people who responded to the surveys. This included 107 SIPE cases, and 873 controls who had not experienced SIPE. The findings showed that wearing a wetsuit (particularly a tight wetsuit) was a risk factor for SIPE, with strong evidence for causality between tight wetsuit use and SIPE. However, the case series showed that SIPE can also affect people that do not wear a wetsuit, particularly long distance swimmers. Having an asthma diagnosis was also strongly associated with SIPE, however, evidence for a causal association was limited, and it is possible my case definition lacked specificity i.e. the criteria may have been too broad meaning it was not possible to differentiate between symptoms of asthma and symptoms of SIPE, resulting in asthma symptoms being mistaken for SIPE. My analysis indicated that higher effort levels, water temperatures of ≥12°C and above, and a BMI <22kg/m^2 were associated with SIPE, however, these effects are likely to be due to confounding. Not drinking alcohol in the previous six months was also associated with SIPE, although the lack of any visible trend with decreasing levels of alcohol consumption suggests the association may be explained by a characteristic or behaviour of non-drinkers that was not measured in this study. I did not find any association between SIPE and age, sex, swimming distance, exertion, or a history of heart disease, hypertension or Raynaud's syndrome.

8.2.4 What are the short-term outcomes of SIPE?

The only primary data on short-term outcomes that I collected was whether people who experienced SIPE received medical attention for their symptoms. I also knew that all participants of the study had survived their episode of SIPE, so there would have been no fatalities. My case series results showed that only seven cases (6.5%) sought medical care. Two of these cases received medical care onsite, three were taken to A&E, one underwent a chest x-ray at hospital, and two visited their GP. All three cases that were transferred to A&E were admitted to a ward and stayed for at least three days. They had all been taking part in a long distance sea swim, including two cross Channel attempts.

8.2.5 What is the recurrence rate of SIPE?

My study did not include a follow-up period, therefore it was not possible to calculate a recurrence rate. However, 70% of the 107 cases in the case series said their episode of SOB was a recurrence of a previous episode, with a fifth of cases having experienced a total of five or more episodes.

8.3 Other key findings

The next section describes some additional key findings that may be of interest to researchers. These are related to the systematic review, symptoms of SIPE, and perceived attribution of symptoms.

8.3.1 Systematic review

My systematic review was the first study to bring together all the available evidence on SIPE occurrence, risk factors, outcomes and prevention. The heterogeneity of the 14 studies included made it difficult to draw conclusions. My findings indicated SIPE affects approximately 1.4% of triathletes and incidence ranged from 0.01% of triathlons raced in the UK to 26.7% of time trials swum by Israeli military trainees. Risk factors included female sex, age over 30 years, hypertension, taking fish oil supplements and long course triathlon distance, as well as lower lung volumes and flows, and higher pulmonary artery pressures during exercise in cold water. In most cases SIPE symptoms resolved rapidly, however, there was some evidence of symptoms persisting for over five days. Hospitalisation was an infrequent occurrence. SIPE recurrences were experienced by 9% to 25% of swimmers that were followed up. Two very small uncontrolled studies of the effect of sildenafil for recurrence prevention were inconclusive.

8.3.2 Symptoms of SIPE

Over a third of 107 participants in my case series said they had no symptoms other than SOB during their SIPE episode. Tightness in the chest was the most common additional symptom, followed by wheezing or whistling/crackling sound in the chest, and an unexplained cough. Only 10 cases reported coughing up sputum.

8.3.3 Perceived attribution of symptoms

The majority of participants in the case series did not attribute their SOB to SIPE unless it had been previously diagnosed, citing other suspected causes such as cold shock, asthma, nasal allergies, respiratory infections, panic, tight wetsuit and exertion.

8.4 Study strengths and limitations

The next section compares my work to previously published studies and discusses the main strengths and weaknesses in the approach I took.

8.4.1 Survey instruments

As far as I am aware, the questionnaires developed in this study are the first survey instruments specifically designed for identifying SIPE cases and collecting information on risk factors and outcomes that have gone through a rigorous testing and refining process. The questionnaires were the product of online testing, in depth cognitive interviews with outdoor swimmers and feedback from a panel of experts. I found only two other studies that used questionnaires to detect cases of SIPE, however, neither of them had undergone validation (Shupak *et al.* 2000; Miller, Calder-Becker and Modave 2010). The SIPE case definition I tested showed reasonable sensitivity and specificity, and high positive and negative predictive values. It also had high criterion validity when compared to SIPE medical diagnosis as the gold standard. This suggests the questionnaires were accurate and valid instruments for detecting cases of SIPE.

There were a number of limitations to my questionnaire development process. For example, the final versions of the questionnaires were not themselves fully validated and would have benefitted from additional testing, however, this was not possible in the time available. In particular, test-retest reliability tests would have allowed me to examine internal validity. Expert panel feedback was limited to just three experts and related to a subset of questionnaire items rather than the full questionnaires. The absence of a scoring matrix meant it was not possible to investigate content validity quantitatively. Although participants of questionnaire testing and cognitive interviews lacked ethnic diversity, the proportion from non-White backgrounds was comparable to the respondents of surveys conducted by Outdoor Swimmer magazine (Outdoor Swimmer 2022; Outdoor Swimmer 2021). It would have been useful to gather additional information such as the severity of SOB and other symptoms, swimming stroke used and details of the swimming environment, however, this would have made the questionnaire longer which could potentially have reduced completion rates.

8.4.2 Prevalence study

To my knowledge, this study is the first cross-sectional study to examine prevalence of SIPE among outdoor swimmers in the UK. The only other published study to have investigated this reported a prevalence of 1.4% of US triathletes (Miller, Calder-Becker and Modave 2010). My prevalence estimates ranged from 0.1% to 22.2%, the upper end of which may be explained by my use of a much broader SIPE case definition compared to Miller, Calder-Becker and Modave (2010), which will have identified many milder case of SIPE. My study participants were also a much more heterogeneous group, which included many different types of outdoor swimmers, rather than being limited to triathletes. This high level of heterogeneity may have made the study less generalizable since it is not clear what type of swimmer the prevalence estimates can be applied to.

My study was subject to a number of sources of bias. For example, where known, the response rates to Hever Castle event surveys were very low at 1.5% to 2.5% of competitors. This may have increased the risk of response bias whereby nonresponse is unequally distributed among those invited to take part. These response rates, however, were no lower than that the 1.3% of the triathlete population who responded to the survey conducted by Miller, Calder-Becker and Modave (2010). Selection bias may have resulted from the exclusion of people who had given up outdoor swimming due to a SIPE event. This could have led to underestimates of prevalence (information bias). There may also have been some information bias and selection bias present caused by the double counting of some respondents who responded more than once, but gave a different email address each time. However, my study did have the advantage that the questionnaires went through a comprehensive testing and validation process, which should have reduced the risk of information bias due to issues with the survey instrument.

8.4.3 Incidence study

In contrast to most other SIPE incidence studies, I used a broad set of criteria in my case definition that did not require a cough or sputum, and did not restrict data collection to swimmers that received medical attention. As a result, my survey was able to detect much milder cases of SIPE that many other studies would have missed. Shupak *et al.* (2000) were the only other incidence study to collect data through a post-swim questionnaire, however, unlike my study, their questionnaire did not undergo a testing and validation process. My incidence estimates of 2.8% to 14.8% fell within the range reported by eight published studies, from 0.01% of triathlons raced in the UK (Smith *et al.* 2017) to 26.7% of swimming time trials performed by Israeli military trainees (Adir *et al.* 2004). However, the high heterogeneity of the studies in terms of swimming environment, population characteristics and denominators, and SIPE case definition, means it is difficult to make fair comparisons.

My incidence study was subject to a number of limitations. For example, the small sample size will have reduced precision and limited the generalisability of incidence estimates. The very low survey response rates would have increased the risk of a response bias, and potential double counting of respondents who used multiple email addresses could have led to information bias and/or selection bias.

8.4.4 Risk factors study

My risk factors study used robust methods to develop logistic regression models using a large sample of data collected in my surveys of outdoor swimmers. I spent an extended period analysing each individual risk factor variable, which involved descriptive statistics, univariate associations, examining collinearity and identifying confounding variables. I developed regression models that adjusted for both age and sex, and carried out detailed investigations into causality. To my knowledge, no other published studies have involved such extensive analyses of a large number of proposed risk factors for SIPE.

My findings that wetsuit use is a risk factor is consistent with some of the initial findings of Miller, Calder-Becker and Modave (2010) in their unadjusted univariate analyses, but the association disappeared in their final multivariate model (although this did not adjust for age). To my knowledge, no other large studies have identified asthma as a risk factor, although Hårdstedt *et al.* (2021) reported higher than expected asthma prevalence among competitors of a Swedish open water swimming event. A follow-up study of competitors who sought medical treatment for SIPE found being asthmatic increased the likelihood of symptoms lasting for two days, and of experiencing a recurrence (Kristiansson *et al.* 2023).

The risk factor study was subject to many types of bias. For example, misclassification may have occurred if responses to questionnaire items did not accurately reflect the true situation. Reference periods were different for cases and controls i.e. cases were asked about the time of their most recent episode of SOB and controls were asked about their most recent outdoor swim. Recall bias could have been an issue if respondents had difficulty remembering details about their last swim/episode of SIPE, or if they had presumptions about the cause of their SOB.

Cases and controls were not randomly chosen, which may have caused selection bias. Type 1 errors (false positives) may have resulted from multiple statistical analyses being conducted using the same sample, and Type 2 errors (false negatives) could have been caused by the conversion of continuous variables to categorical variables. Although I attempted to identify and adjust for confounding variables, this was limited to those variables included in the dataset.

8.4.5 Case series

My SIPE case series includes 107 cases, which makes it the one of the largest studies of this type that reports primary data. It describes important information relating to the characteristics of reported SIPE episodes, such as associated symptoms, perceived attribution of symptoms, medical treatment and previous similar episodes. It also includes a detailed account of the experiences of three swimmers who experienced symptoms compatible with SIPE. In contrast to most other SIPE case series, this study involves a heterogeneous group of outdoor swimmers and includes individuals who experienced milder symptoms with no medical intervention, as well as very serious SIPE events where swimmers were pulled out of the water and airlifted to hospital. This inclusion of milder cases in the sample led to some novel findings. For example, over a third of patients had no symptoms other than SOB. This is in contrast to most published studies where SIPE case definitions or diagnostic criteria require the presence of addition symptoms such as cough, wheeze, whistling/crackling in chest or coughing up sputum.

The most common symptom experienced by cases in addition to SOB was chest tightness, which was reported in very few cases reviewed by Grünig *et al.* (2017) and Hohmann, Glatt and Tetsworth (2018). The authors also found unexplained cough and coughing up sputum to be much more prevalent compared to my sample. I did not collect any information on duration of SIPE symptoms, so was not able to comment on recovery times.

By collecting information on the attribution of symptoms by respondents, my case series highlights the challenges of recognising SIPE when symptoms can often be mistaken for cold shock, panic attack, or other respiratory problems such as asthma, nasal allergies, and respiratory infections.

My results suggested that admissions to hospital for SIPE are not a common occurrence, which is consistent with the findings of four earlier studies (Adir *et al.* 2004; Volk *et al.* 2021; Kristiansson *et al.* 2023; Sebreros *et al.* 2023). I was not able to calculate a recurrence rate due to the absence of a follow-up period. However, compared to previous studies, I found a much higher proportion of reported SIPE events were recurrences of previous episodes of SOB (Shupak *et al.* 2000; Braman Eriksson, Annsberg and Hardstedt 2017).

8.5 Summary of key findings

The results of this PhD study reveal that:

1.SIPE is probably more common than previously thought.

2.SIPE may be more frequently a recurrent condition than formerly believed.

3.Wetsuits may contribute to getting SIPE, particularly if they are tight fitting.

4.SIPE does not appear to be more common in women or in any particular age group.

5.Apart from wetsuit use, none of the previous hypothesised risk factors were risk factors in my study.

6.Awareness of SIPE among outdoor swimmers is limited.

It is therefore important to learn more about SIPE through conducting more research and to raise awareness of the issues so they can be addressed by policy and practice.

8.6 Recommendations for future research

In this section, I will put forward ideas for future research that can address the remaining unanswered questions about SIPE. This includes studies that can improve our understanding of SIPE occurrence, risk factors, outcomes, prevention and pathophysiology, as well as studies that measure awareness of SIPE among health professionals, event organisers and people who run open water swimming venues.

8.6.1 Occurrence of SIPE

Further studies are necessary to increase our understanding of the occurrence of SIPE among different types of open water swimmer, such as recreational endurance swimmers, military swimmers and triathletes. Large samples of similar types of open water swimmer would produce more generalisable and precise prevalence and incidence estimates.

Prevalence could be investigated using a cross-sectional study of members of outdoor swimming or triathlon organisations (similar to Miller, Calder-Becker and Modave 2010), competitors of large outdoor swimming or triathlon events, or subscribers to magazines such as Outdoor Swimmer or 220 Triathlon. In fact, Outdoor Swimmer magazine have recently conducted their own surveys of members (Outdoor Swimmer 2022; Outdoor Swimmer 2021), which through collaborative efforts, could offer a means of conducting future research. In order to reflect the true burden of SIPE, questionnaire items that can detect milder symptoms should be used.

Incidence could be investigated through prospective cohort studies that track a large group of regular outdoor swimmers over time. Ideally, the group would be SIPE free at the beginning of the study and baseline information collected for each participant. Regular follow-ups would then take place to collect data and monitor for symptoms of SIPE.

8.6.2 Risk factors

Further studies into risk factors for SIPE, in particular wetsuit use, will help to better predict who is most at risk of experiencing an episode. Existing evidence on wetsuit use as a potential risk factor is limited to the findings of Miller, Calder-Becker and Modave (2010), which showed there was a univariate association between SIPE and wetsuit use, however, the association disappeared in subsequent multivariate regression models. Investigations into the effects of wetsuit tightness and other wetsuit related factors such as thickness, elasticity and shape, on ORs for SIPE would be useful.

Future research into risk factors should also try to replicate the findings of Shupak *et al.* (2000), Sebreros *et al.* (2023), Miller, Calder-Becker and Modave (2010), Moon, Martina, Peacher, Potter, *et al.* (2016) and Hårdstedt *et al.* (2021), and explore other hypothesized risk factors, such as lack of cold water habituation, over hydration, water temperature, swimming stroke, fitness level, exertion, presence of respiratory pathogens or specific gene variants, heart conditions, failure to warm up, and variations in physiological stress response. Risk factor study designs could include cohort studies or case control studies. The former would involve observing a group of individuals over a long period to see who develops the disease based on exposure to risk factors. Alternatively, a case control study would provide a more time efficient and cost-effective method for identifying risk factors, although cohort studies are better for establishing temporal relationships between an exposure and the disease.

8.6.3 Outcomes

It is thought that SIPE symptoms usually resolve quickly, however, there is some evidence that in some individuals symptoms can persist beyond five days (Kristiansson *et al.* 2023; Adir *et al.* 2004). Studies that investigate the presence of symptoms in the days and weeks following an episode of SIPE would be useful to get a better understanding of symptom duration.

More cohort studies that follow up individuals with a history of SIPE, similar to Kristiansson *et al.* (2023) would help to improve our understanding of long term health outcomes. Participants could include SIPE-susceptible swimmers identified in previous incidence, prevalence or risk factor studies. Baseline data would need to be collected, with follow-up assessments conducted every 6 to 12 months for between two and five years. Data could be collected on indicators of respiratory, cardiovascular and general health. This could include lung function tests, chest imaging, a questionnaire on chronic respiratory symptoms, blood pressure readings, and monitoring any new health conditions that develop through a review of medical records.

8.6.4 Recurrence rates

Cohort studies, similar to those mentioned in section 8.6.3 above, would also help to explore the frequency and timing of recurrent episodes of SIPE among affected individuals.

8.6.5 SIPE prevention

SIPE prevention is a particularly under-researched area. My systematic review identified only two small studies, both of which examined the effect of sildenafil on pulmonary artery pressures (Moon, Martina, Peacher, Potter, *et al.* 2016; Martina *et al.* 2017). Randomised controlled trials are needed to determine the efficacy of sildenafil as a method for preventing recurrences. Studies should also investigate other strategies in reducing the risk of SIPE, such as avoidance of tight fitting wetsuits, medication to control hypertension, cold water habituation, changes in swimming technique, or hydration management.

8.6.6 Physiological studies

There is a need for more research that investigates the physiological mechanisms that are thought to cause SIPE. This could include experimental studies into the haemodynamic shifts and changes in pulmonary artery pressures that occur during exercise in cold water. The studies could involve a cardiopulmonary exercise challenge, which compares the responses of a group of individuals with a history of SIPE, with a control group. Participants would be asked to swim in a flume while measurements such as pulmonary artery pressures, central venous pressure, heart rate and peripheral oxygen saturation are taken. Monitoring for early signs of fluid accumulation in the lungs could be done through pulmonary tests or imaging techniques such as ultrasound scans. This type of study could also examine the effects of wearing wetsuits of varying tightness, thickness and elasticity, differing levels of fluid intake, and different water temperatures. The effect of short bursts of high intensity exercise versus long duration endurance swimming would also be a useful area to study.

8.6.7 Developing a standardised case definition

Comparing studies of SIPE is often challenging due to the array of different case definitions that are used. Standardising an epidemiological case definition for SIPE would improve the comparability of studies and enable the pooling of data so that meta-analyses can be conducted, which would generate more accurate and comprehensive estimates. This standardisation work could be done using the Delphi consensus method, whereby experts from fields such as medicine, physiology and sports science could work together following a systematic process, resulting in an agreed-upon case definition. This would be similar to the process used to develop a clinical case definition for post-COVID-19 condition, otherwise known as long COVID (Soriano *et al.* 2022).

8.6.8 Impact of SIPE on drowning

There are a large number of unexplained drowning deaths, for example 755 over a five year period (National Water Safety Forum 2020; 2021; 2022; 2023; 2024), some of which may be potentially due to SIPE. An investigation of coroner's reports of unexplained swimming related deaths, similar to that carried out by Moon *et al.* (2016) would help to establish how common SIPE might be as a cause of drowning related death in the UK. This would involve examining post mortem reports, with particular attention paid to details of any pre-existing cardiovascular or respiratory conditions and the circumstances of death, such as the type of swimming activity, duration and intensity of swimming, water temperature and wetsuit use. Standardised criteria would need to be applied in order to classify deaths as "possible SIPE" or "probable SIPE".

8.6.9 Awareness of SIPE

Increasing the awareness of SIPE among health professionals, event organisers and people who run outdoor swimming venues, would help to improve prevention, early detection and management of SIPE. In order to a plan an awareness campaign or intervention, it is necessary to understand current levels of awareness. This could be done through conducting surveys, interviews or focus groups with health professionals, event organisers and venue managers to understand the level of familiarity with SIPE, including symptoms, risk factors, management of cases and safety protocols.

8.6.10 Conclusions

Some of the above recommendations could be considered unrealistic or unfeasible by reviewers or policy makers due to the practicalities and/or costs involved. However, they all stem from the importance of increasing the awareness of SIPE among all open water swimming stakeholders, and the need for more evidence so the condition can be diagnosed and treated quickly and effectively and measures taken to prevent recurrences in at-risk individuals. Ultimately, this will help to improve the safety of outdoor swimming for all those who benefit so much from it.

8.7 Implications for policy and practice

This section considers the implications for all stakeholders in open water swimming.

8.7.1 Recommendations for the outdoor swimming community

Outdoor swimming is known to have many health and wellbeing benefits, so it is important not to frighten swimmers or discourage them from taking part. However, increasing their knowledge and awareness of SIPE is essential to reduce the number of occurrences and minimise the risk of harm. Based on the most recent estimates that 4.4 million people in England went open water swimming in the last year, the results of my prevalence study suggests there are almost 400,000 individuals who might have previously experienced SIPE (Sport England 2024). Swimmers need to know about the symptoms associated with SIPE, what action to take whilst experiencing an episode, and what might help to prevent an occurrence or recurrence. Swimmers should be advised to get out of the water as soon as possible during an episode and get medical help if symptoms do not resolve quickly. Seeking a medical check-up soon after the event to test for any relevant undiagnosed health conditions may also be advisable. Preventative measures could include wearing a looser fitting wetsuit, and in some extreme cases, avoiding cold water swimming altogether. General water safety advice also applies such as avoiding swimming alone, entering cold water slowly, using a brightly coloured swim cap and tow float, and checking the conditions are safe before entering the water.

According to the Outdoor Swimming Society, a large proportion of outdoor swimmers are members of local outdoor swimming/triathlon clubs, informal groups and networks (Couch 2023). Information and guidance regarding SIPE could be disseminated to swimmers via national outdoor swimming organisations that already publish outdoor swimming safety advice (see section 8.7.2 below). Articles in outdoor swimming and triathlon magazines and newsletters, as well as national newspapers, would also help raise awareness of SIPE among outdoor swimmers. Posters about SIPE at outdoor swimming venues and events could also be used.

8.7.2 Recommendations for national outdoor swimming organisations

Outdoor swimming safety advice and guidance is published by many different organisations in the UK. These include Triathlon England, Swim England, British Long Distance Swimming Association and the Channel Swimming Association, as well as the National Water Safety Forum, Royal Life Saving Society, and Royal National Lifeboat Institution. It is important that this guidance includes up to date and accurate information on SIPE as a potential risk for outdoor swimmers, and advice on preventative measures and what action to take if it occurs. Specific guidance should be produced for outdoor swimmers, clubs and groups, venue operators and event organisers. Consideration should be given to setting up a working group to develop a comprehensive set of guidance relevant to each type of stakeholder. This would ensure the messages are consistent and minimise duplication of effort across organisations.

8.7.3 Recommendations for outdoor swimming venues

A recent survey reported that 29% of outdoor swimmers in England use commercial outdoor swimming venues weekly or more frequently (Outdoor Swimmer 2022). Therefore, increasing the awareness of SIPE by outdoor swimming venue operators is crucial in reducing the risk of harm from this condition. It is important that staff working at venues understand the risks of SIPE, recognise the symptoms and can offer the right kind of assistance to swimmers when necessary. This may require closer monitoring of individuals in the water, procedures for pulling affected swimmers out of the water quickly, and knowledge of appropriate first aid to give.

Outdoor swimming venues are subject to a variety of UK legislation regarding health and safety, environmental protection and public health, although there are no specific regulations related to the supervision of swimmers, safety equipment, swimmer numbers and emergency support. A number of organisations, however, provide voluntary guidance regarding best practice for safety at open water swimming venues. These include the Royal Life Saving Society, Swim England, The Outdoor Swimming Society, Health and Safety Executive and British Triathlon. Outdoor swimming venue operators should be made aware of these documents and encouraged to follow the guidance. As discussed earlier, it is important that these guidance documents include specific information and advice related to SIPE.

There are also voluntary schemes and initiatives that have been set up to improve safety at organised venues, which venue operators should be encouraged to sign up to. For example, Beyond Swim is an accreditation initiative set up by Triathlon England and supported by Swim England and the Royal Life Saving Society, which ensures that open water swimming venues follow best practice guidelines and meet safety standards. However, take up has been limited, with only six open water swimming venues in England fully accredited as of October 2024. The National Open Water Coaching Association (NOWCA) also set up an outdoor swimming safety initiative. It works with open water swimming venues to ensure safety protocols are followed, provides technology such as safety wristbands and apps for swim tracking, and offers members coaching and access to safe open water swimming venues and events. There are currently 45,000 members and 47 venues in the UK that are affiliated with NOWCA (2024).

8.7.4 Recommendations for outdoor swimming event organisers

There are no specific all-encompassing regulations for outdoor swimming events, however, they are subject to several UK regulations regarding health and safety, water quality, lifeguard provisions, insurance, emergency procedures and environmental considerations. In particular, event organisers are legally required to conduct risk assessments specific to the event and location. National governing bodies such as British Triathlon have published documents stating the requirements for affiliated triathlon events, and safety guidance has been produced by organisations such as the Royal Life Saving Society, Swim England, and the Outdoor Swimming Society. However, for non-affiliated events organised by private companies, charities and local clubs, there is no requirement to follow the guidance. Therefore, it is important that these event organisers are encouraged to follow best practice safety guidelines to reduce the risk of harm from SIPE.

8.7.5 Recommendations for healthcare professionals

An increase in the awareness of SIPE among healthcare professionals is necessary to ensure that the condition is recognised quickly and appropriate medical care given. This includes event medical teams, St John's Ambulance volunteers, paramedics and emergency care practitioners. Awareness should also be raised among wider healthcare professionals so that appropriate medical advice can be given to SIPE susceptible individuals to help prevent a recurrence. This information could be disseminated through professional colleges and associations, such as the Health and Care Professional Professionals Council and Association for Paramedics. The British Thoracic Society (BTS) produces clinical statements that summarise current understanding and best practice in a specific clinical area. For example, there is a BTS clinical statement for the assessment and management of respiratory problems in athletic individuals, which includes SIPE (Hull *et al.* 2022).

8.7.6 Recommendations for policy makers

In the following section, I discuss possible options for policy makers such as regulation, surveillance and standardising of the SIPE case definition and clinical criteria.

8.7.7 Regulation

There has been some debate about the need for tighter regulation of outdoor swimming venues and events to ensure swimmers are not put at unnecessary risk of harm. Many within the outdoor swimming community feel that tighter regulation would have negative consequences, such as restricting access to wild swimming, the closure of smaller or more informal venues, an increase in the cost of accessing venues, and over-commercialisation of popular wild swimming locations. They argue that regulation is unnecessary and that many swimmers prefer to assess the risks themselves and take personal responsibility for their own safety. They suggest that community based solutions such as volunteer lifeguards and monitoring of conditions by local swimming groups are just as effective at improving safety as mandatory regulations.

8.7.8 Surveillance

There is currently no register or database of individuals in the UK who have previously experienced SIPE, which makes studying this condition challenging. A surveillance system whereby occurrences of SIPE are reported and recorded in a centralised database would be an extremely valuable resource for future research studies. Such systems are already in place for a group of “notifiable” infectious diseases, for which there is a legal requirement to report cases to the UK Health Security Agency (Gov.uk 2024). This includes COVID-19, Measles, SARS (Severe Acute Respiratory Syndrome) and Tuberculosis, among many others. There are also non-statutory disease registers for cancer, and congenital anomalies and rare diseases, as well as GP disease registers for a number of chronic conditions (NHS England 2024a; NHS England 2024b).

The Rare Disease Registration Service is a database that holds information on patients diagnosed with specific rare diseases that affect no more than 1 in 2,000 people. It is an important part of the Rare Disease Framework that was set up to improve diagnosis of rare diseases, increase awareness among healthcare professionals, and improve coordination of care and access to specialist treatments. The Rare Disease Registration Service collects data from a number of sources such as NHS hospitals, specialist clinics, GPs, laboratories, patients themselves and existing databases (NHS England 2024a). It includes information on demographics, diagnosis, treatment, outcomes, disease progression, genetic data where applicable and medical history. The data are used for a number of purposes including disease surveillance, research and development of new treatments, developing new diagnostic tools, clinical improvement and providing insights for policy making and resource allocation. The Rare Disease Registration Service could provide a model on which to base a new surveillance system of SIPE. A new working group could be set up to develop a method of SIPE surveillance, which could consider the above option.

8.7.9 Standardised case definition and specific diagnosis code

An accurate surveillance system depends on having a standardised SIPE case definition, but this does not currently exist. Case definitions used in research studies vary from mild SOB to patients presenting to medical teams with severe SOB accompanied by a cough and bloody sputum. Therefore, consideration should be given to setting up a working group involving a range of experts, to work towards developing a standard case definition for SIPE.

There is also no specific ICD (International Classification of Diseases) diagnosis code for SIPE. This makes it impossible to accurately identify cases of SIPE from hospital records, without access to patient notes. This is something that can be addressed through the submission of a proposal for a new ICD code to the World Health Organization ICD-11 maintenance platform. This could be done through a working group including health professionals, researchers and other stakeholders.

8.7.10 Additional recommendations regarding wetsuits

It is important that swimmers that are buying or hiring a swimming wetsuit are given the correct advice regarding its fit. A warning of the increased risk of SIPE whilst wearing a wetsuit that is too restrictive or tight fitting could be given to customers by staff at wetsuit retailers or hire centres. Warnings about the risk of wearing a wetsuit that is too tight/restrictive could also be put on wetsuits, that are visible throughout the lifetime of the wetsuit. In addition, posters that explain the dangers of swimming in a tight fitting wetsuit could be displayed at outdoor swimming venues and events.

8.7.11 SIPE cards

A credit card sized plastic card that indicates a person is an open water swimmer and includes information about SIPE risk factors, symptoms, first aid and possible treatment, has been developed by Dr Ruth Williamson. These cards were designed for open water swimmers to carry to raise awareness of SIPE and advise that the condition should be considered alongside other diagnoses if particular symptoms and risk factors are present in the swimmer. More widespread use of this type of card should be considered in future.

8.8 A personal reflection of the doctoral process

My choice of subject matter was motivated by my personal experience of SIPE during a lake swim in 2016. The shortage of information about the condition and why it affects some people and not others drove me to try to find answers. It was, in hindsight, a very ambitious goal for an environmental scientist turned health analyst/researcher with very little knowledge and understanding of human physiology. Trying to balance studying with work and home life was at times very difficult, particularly during the COVID-19 pandemic, changes of employment, and a family bereavement. However, the multi-disciplinary nature of this study made it a very interesting topic and gave me the opportunity to acquire knowledge on a range of subjects and develop many new research skills. For example, I became skilled in conducting systematic reviews, questionnaire design and testing (including cognitive interviewing), carrying out surveys and analysing data using Stata/IC 16 (Stata Statistical Software, Release 16. College Station, TX: StataCorp LLC.). I also increased my understanding of non-communicable disease epidemiology and acquired a working knowledge of the human cardiorespiratory system.

One of my biggest challenges was achieving a large enough sample of survey responses to enable risk factors to be studied with any reasonable precision. This led to me spending another seven months creating a new questionnaire and conducting an additional survey. However, by this stage, I had learned the importance of forming collaborations and promoting the survey through social media, which resulted in the collection of over 1,000 responses. The next major challenge was to clean, code and combine all responses from the different surveys into single datasets using a new software package called Stata, and conducting the analyses for the prevalence, incidence and risk factor studies. The process took several years and involved learning many new epidemiological and statistical concepts and then applying them to my datasets using Stata code.

Overall, the PhD process has taught me the importance of developing the softer skills, such as communication, project management and collaboration, which I believe are crucial in achieving success in research. One of the most enjoyable parts was conducting cognitive interviews as part of questionnaire testing. Hearing about the experiences of swimmers who had suffered SIPE episodes and how it had affected them was very interesting and enlightening. It also served as a reminder of the importance of further research into SIPE and the impact a greater understanding of the condition could have on many individuals in the outdoor swimming community.

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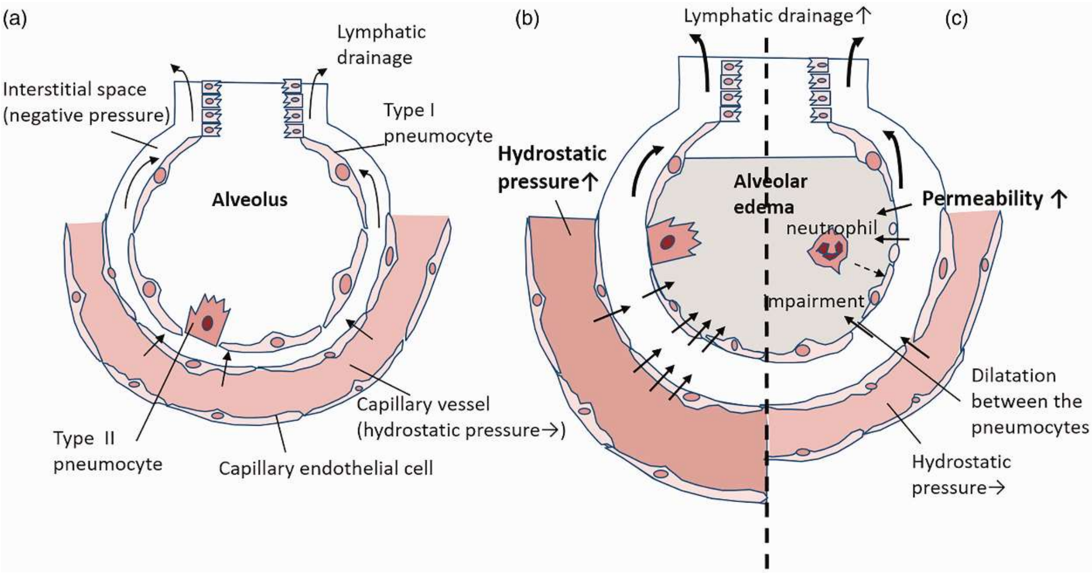
Appendices

Appendix 1: Pathophysiology of pulmonary oedema



(a) Pulmonary capillaries and the pulmonary lymphatic system normally maintain a slightly negative pressure in the interstitial space, and the alveoli are maintained in a "dry" state. Pi is assumed to be negative, so the arrow points outward instead of inward. Pc, capillary hydrostatic pressure; Pi, hydrostatic pressure of the interstitial fluid; πp, colloid osmotic pressure of the plasma; πi, colloid osmotic pressure of the interstitial fluid. (b) Increases in hydrostatic pressure cause transudation of protein-poor fluid into the interstitial spaces and alveoli. The capillary endothelium is much more permeable to water and solutes than is the alveolar epithelium. Edema fluid therefore accumulates in the interstitial space before it accumulates in the alveoli. (c) The alveolar-capillary membrane becomes damaged and leaky in cases of permeability pulmonary edema, allowing increased movement of water and proteins from the intravascular space into the interstitial space and alveoli (Source: Tsuchiya *et al.*, 2020). Reproduced with permission from Sage Publications Ltd.

Appendix 2: Data extraction forms

2a. Incidence

Study ID number	
Author(s)	
Institution	
Title	
Publisher	
Abstract	
Study design	
Publication Type	
Subjects	
Period of data collection	
Country	
Population size	
Sampling frame	
Sample size	
Description of study population	
How sample chosen/inclusion criteria	
Exclusions	
How cases identified	
Case definition	
No. cases identified	
Incidence (%)	
Water temp	
Depth	
Open water/pool	
Wetsuit use	
Mean age	
Health conditions	
Duration of swim/dive	
Findings	
Quality	
Include in review?	

2b. Prevalence

Study ID number	
Author(s)	
Institution	
Title	
Publisher	
Abstract	
Study design	
Publication Type	
Subjects	
Type of activity	
Period of data collection	
Country	
Population size	
Sampling frame	
Sample size	
Description of study population	
How sample chosen/inclusion criteria	
Exclusions	
How cases identified	
Case definition	
No. cases identified	
Prevalence (%)	
Water temp	
Depth	
Open water/pool	
Wetsuit use	
Mean age	
Health conditions	
Duration of swim/dive	
Findings	
Quality	
Include in review?	

2c. Risk factors

Study ID number	
Author(s)	
Institution	
Title	
Publisher	
Abstract	
Study design	
Description of study population	
Risk factors studied	
Period of data collection	
Country	
Population size	
Sampling frame	
Sample size	
How sample chosen/inclusion criteria	
Exclusions	
How cases identified	
Case definition	
No. cases identified	
Comparator/control?	
Water temp	
Open water/pool	
Wetsuit use	
Mean age	
Health conditions	
Previous respiratory distress whilst swimming	
Medication/supplement use	
Duration of swim/dive	
Pre-swim hydration	
Warm up	
Other risk factors	
Findings	
Quality	
Include in review?	

2d. Prognosis

Author(s)	
Institution	
Title	
Source	
Publisher	
Abstract	
Study design	
Country	
Description of participants	
Activity	
Number of cases	
About recurrence/recovery from acute episode/ long term sequelae	
Period of follow up	
Completeness of follow up	
Recovery from initial acute episode	
How recurrence identified	
Definition of recurrence	
Number of recurrences <30 days	
Number of recurrences 30 days +	
Other sequelae	
Quality	
Include in review?	

Appendix 3: Results of assessments of risk of bias

3a. Incidence

Authors	Was the study population clearly specified and defined?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Was loss to follow-up after baseline 20% or less.
Sebreros et al. (2023)	Yes, 1,048 young males who took part in the first phase of Naval Special Warfare (NSW) BUD/S training programme. Mean age of 24.	Partly, all subjects were healthy young men enrolled in Phase 1 of NSW training between 11th Dec 2020 and 26th Nov 2021. Different time periods depending on dates of classes.	No inclusion/exclusion criteria reported other than programme entry requirements.	No clearly defined or consistently implemented exposure variables. Some information on season and most common activity during which SIPE occurred i.e. 78% during 1 and 2 mile open water swims.	Yes, SIPE case definition was clearly defined and applied consistently to all participants.	Unknown. High attrition rate suggests loss to follow-up may have been high.
Lindqvist et al. (2022)	No, 20 trained long-distance open-water swimmers who took part in an 8 hour swim. Not clear if they were recreational or competitive swimmers (or military?).	Partly – all subjects swam in the same time period, however not clear if they were from the same population.	No, inclusion criteria were not clearly specified other than being a participant in an 8 hour swim.	No exposure measures other than a swim duration of 8 hours were reported.	Yes, SIPE case definition was clearly defined and applied consistently to all participants; Participants with breathlessness and ≥3 B-lines present in 2 or more lung ultrasound views.	Yes, all participants were followed up after the swim.
Hårdstedt et al. (2021)	Yes, 45,913 competitors at the annual Vansbrosimningen open water swimming event, who took part in 47,573 races over 4 years. Competitors were 53% female, aged ≥18 years, and included competitive as well as recreational swimmers.	Partly, subjects were all competitors but included both recreational and competitive swimmers. Time periods varied according to the years in which the competitors took part.	Yes, all adult competitors who took part between 2016 and 2019 were included.	Partly, swimming distance and wetsuit use were reported for SIPE cases, but not the remaining competitors. However, exposure data for competitors as a whole, by year, were included in an online supplement e.g. mean water and air temperatures, swimming distances and swimming speed.	Partly, SIPE case definition varied by year. 2016 based on clinical findings, 2017 used validated diagnostic criteria applied retrospectively, 2018 and 2019 were based on lung ultrasound findings (except for 5 patients for which 2017 definition used).	No, data only collected for competitors seeking medical attention.

Authors	Was the study population clearly specified and defined?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Was loss to follow-up after baseline 20% or less.
Volk et al. (2021)	Yes, 2,117 young males taking part in US Naval Special Warfare (NSW) training programme. Mean age of 23.	Partly, all subjects were young men enrolled in NSW training courses that took place over a 15 month period from February 2018 to April 2019. Different time periods depending on dates of classes.	No inclusion/exclusion criteria other than programme entry requirements.	Cold water exposure time for participants reported in person-days, by water temperature and month.	Separate case definition for definite SIPE and probable SIPE. Both were clearly defined and applied consistently.	Loss to follow-up was not reported.
Smith et al. (2017)	No, 68,557 competitors of 11 triathlons including elite and non-elite competitors. No detail on demographics other than cases of SIPE.	Yes, all subjects were triathletes although time periods for individuals were different depending on the races entered over the 5 years of the study.	No inclusion/exclusion criteria other than race entry requirements.	No, crude measure of exposure: total number of races started by competitors in 2011-2016. No detail on individual races such as number of competitors and distance. No information on the number of races started by individual competitors.	Yes, SIPE clearly defined and identified from medical records. Only applied to triathletes seeking medical attention. Unknown if triathletes had previously experienced SIPE.	No, data only collected for competitors seeking medical attention
Adir et al 2004	Yes, 70 military trainees undergoing swimming time trials between 1998 and 2001 diagnosed with SIPE. No data on trainees without SIPE symptoms. All healthy fit males aged 18-19.	Yes, all subjects were military trainees undergoing a fitness training programme within the 3 year study period.	No inclusion/exclusion criteria other than military requirements.	No, exposure i.e. number of time trials undertaken, not known. No detail on individual time trials except that distances were 2.4-3.6km and of 30-45 mins duration.	Yes, SIPE clearly defined and identified from symptoms and clinical examination. Unclear if participants had experienced SIPE prior to the study.	No, data only collected for SIPE cases

Authors	Was the study population clearly specified and defined?	Were all the subjects selected or recruited from the same or similar populations (including the same time period)?	Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Was loss to follow-up after baseline 20% or less.
Shupak et al. (2000)	Yes, 35 healthy fit military trainees undergoing swimming time trials over 2 months. All males aged 18-19.	Yes, All subjects were military trainees undergoing the same 2 month fitness training programme.	No inclusion/exclusion criteria other than military requirements.	Partly, exposure measured as the total number of time trials undertaken, although unclear how many each trainee swam. Distances were all 2.4-3.6km.	Yes, SIPE clearly defined and detected through a non-validated self-complete questionnaire which also enabled differentiation into severe and mild cases. Unknown if participants had experienced SIPE prior to the study.	Yes, no loss to follow-up after baseline
Weiler-Ravell et al. (1995)	Yes, 30 military trainees undergoing a swimming time trial. All males aged 18-19.	Yes, all subjects were military trainees undergoing the same swimming time trial.	No inclusion/exclusion criteria other than military requirements.	Yes, exposure was the same for all swimmers: distance of 2.4km in 23°C calm open sea waring bathing suit with very high hydration levels	Yes, SIPE clearly defined and identified from symptoms observed. Unknown if participants had experienced SIPE prior to the study.	Yes, no loss to follow-up after baseline.

(Adapted from Source: NHLBI 2014)

3b. Prevalence

Authors	Was the sample representative of the target population? (selection bias)	Was the likelihood of non-response bias minimal?	Was the study instrument that measured the parameter of interest shown to have validity and reliability? (measurement bias)	Was the same mode of collection used for all subjects? (measurement bias)	Were the numerator(s) and denominator(s) for the parameter of interest appropriate? (analysis bias)
Miller et al 2010	Yes, large sample size (n=1400) and no sig. difference between age distribution of sample and target population. Exclusions: <20 yrs, incomplete responses.	No, very low response rate of 1.3%	No, all data collected through self-completed non-validated standardised questionnaire.	Yes	Yes, numerator was number of respondents reporting history of symptoms of SIPE, denominator was all respondents.

(Adapted from Source: Hoy *et al.* 2012)

3c. Risk factors

Authors	Are the characteristics of the participants included in the study clearly defined?	Were the subjects who were prepared to participate representative of the entire population from which they were recruited? (selection bias)	Were the cases and controls/comparators recruited from the same population? (selection bias)	Were the main outcome measures accurate (valid and reliable)? (measurement bias)	Were the statistical tests used to assess main outcomes appropriate? (analysis bias)	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?
Sebreros et al. (2023)	Yes, 113 military trainees in Phase 1 of US Naval Special Warfare training.	Yes, subjects were likely to be representative of the military trainee population in terms of age and gender.	Yes, but controls were selected from a different cohort to cases and, unlike cases, did not participate in swimming events before data collected.	Yes, although not formerly validated, SIPE case definition was clearly defined and applied consistently to all participants.	Chi-squared test used to determine whether there was a significant difference between the proportion of positive respiratory panel test results in this cases compared to controls.	Yes
Hårdstedt et al. (2021)	Yes, 45,913 competitors at Vansbrosimningen open water swimming event who swam 47,573 distances from 2016-2019. Participants were aged ≥18 years, 53% female, and included competitive and recreational swimmers.	Yes, all adult competitors were participants.	Yes, cases and controls were all event competitors.	Yes, validated diagnostic criteria or lung ultrasound findings used to identify SIPE cases, except in 2016 (and for 5 patients in 2017).	Yes, univariate and multiple logistic regression used to investigate age and sex as risk factors for SIPE.	Yes
Volk et al. (2021)	Yes, 2,117 military trainees in US Naval Special Warfare training between 2nd February 2018 and 30th April 2019.	Yes, subjects were likely to be representative of the military trainee population in terms of age and gender.	Yes, cases and controls were all trainees who took part within the 15 month time period.	Case definitions for definite or probable SIPE were not validated, although definite SIPE was clearly defined. Probable SIPE was less clearly defined and more open to interpretation.	Incidence of SIPE (cases per person-days) was calculated for different water temperatures.	No, SIPE incidence tended to be higher at lower water temperatures, although no clear or consistent trend.

Authors	Are the characteristics of the participants included in the study clearly defined?	Were the subjects who were prepared to participate representative of the entire population from which they were recruited? (selection bias)	Were the cases and controls/comparators recruited from the same population? (selection bias)	Were the main outcome measures accurate (valid and reliable)? (measurement bias)	Were the statistical tests used to assess main outcomes appropriate? (analysis bias)	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?
Moon et al. (2016)	Yes, subject characteristics are reported.	Unclear, no comparisons are made between participants and the target population. Unknown how SIPE subjects were chosen.	No, although cases and controls were similar in age, BMI and race, cases had a higher proportion of females and may have been physically fitter.	Inconsistency in the way pre-exercise measurements were taken i.e. SIPE subjects were supine while controls were sitting.	Yes, appropriate statistical tests were used to analyse the data.	Yes
Miller, Calder-Becker and Modave (2010)	Yes, survey respondents are clearly defined (however no information on the additional 11 cases from slowtwitch)	Yes, no sig diff between age distribution of survey sample (n=1400) and target population (representativeness of 11 cases from slowtwitch is unclear)	Mostly. Controls were survey respondents but cases were made up of both survey respondents and 11 slowtwitch contributors	No, outcome measure of SIPE was detected using non-validated self-completed questionnaire	Yes, exploration of univariate risk factors and use of multiple logistic regression to determine predictors of SIPE	Yes
Shupak et al. (2000)	Yes, 35 healthy fit military trainees undergoing swimming time trials over 2 months. All males aged 18-19.	Yes, although the sample size is small, it is likely to be representative of the military trainee population in terms of age and gender	Yes, cases and comparators from within the cohort	Self-reported level of exertion was subjective, lung function tests used calibrated spirometer	Yes, Spearman's rank test for correlation between exertion and occurrence of SIPE, one way ANOVA and Tukey test to compare lung function between groups	Yes

(Adapted from Downs and Black 1998)

3d. Prognosis

Authors	Are the characteristics of the participants included in the study clearly defined?	Were the subjects who were prepared to participate representative of the entire population from which they were recruited? (selection bias)	Were the main outcome measures accurate (valid and reliable)? (measurement bias)		
			Short term outcomes i.e. hospitalisations and recovery	Recurrence	Long term sequelae
Kristiansson et al. (2023)	Yes, competitors of Swedish open water swimming event that attended the mobile medical unit (MMU) and were diagnosed with SIPE at the event (for 10 day follow-up) or retrospectively (for 30 month follow-up). Mostly female (≥89%) non-smokers with mean age of 48. Median BMI of 23 or 24 kg/m^2 with varying swimming experience. Some diagnoses of asthma, hypertension and heart disease.	No, much higher prevalence of subjects were female (≥89%), compared to all event competitors (53%) in the study period.	Partly, short term outcomes came from MMU data and partially validated follow-up questionnaire used for telephone interviews (with the opportunity to clarify questions and answers). Self-reported details on symptom duration and any further medical attention. Those who had further medical attention were also asked to provide medical records.	Partly, MMU patients were asked about previous breathing problems/coughing when swimming in open water. Follow-up questionnaires asked if respiratory symptoms had been experienced again, although no information on time lag.	Yes, 30 month follow-up questionnaire collected details of medical history. It also asked about general health status and levels of physical activity, using modified questions taken from validated survey instruments.
Sebreros et al. (2023)	Yes, 45 military trainees who were previously diagnosed with SIPE whilst participating in US Navy SEAL BUD/S training. All healthy fit males with mean age of 24.	Yes, subjects are likely to be representative of military trainee population in terms of age and sex.	Yes, whether trainees returned to training after recovery from SIPE, or were hospitalised. No deaths occurred.	Yes, trainees who were experiencing a recurrence were reported. Time lag was not stated.	Not reported
Volk et al. (2021)	Yes, 106 military trainees who were diagnosed with SIPE during in US Naval Special Warfare training programme. All healthy fit males with mean age of 23.	Yes, subjects are likely to be representative of military trainee population in terms of age and sex.	Yes, whether trainees returned to training following SIPE, or were admitted to ICU and recovered rapidly. No deaths occurred.	Yes, recurrences within study period were reported, although time lag specified only as “several weeks” later.	Not reported
Melau et al. (2019)	Yes, 3 triathletes (one professional) who took part in Extreme triathlon in Norway.	No, very small sample, one of whom was a professional triathlete.	Yes, 2 triathletes were admitted to hospital overnight. All recovered within 24 hours.	Not reported	Not reported
Braman Eriksson et al 2017	No, 13,878 swimmers at a 3 day open-water swimming event. No detail on demographics other than cases of SIPE.	Unclear, no demographic information on the at risk population of open-water swimmers including multi-sport endurance athletes.	Yes, reported that all symptoms resolved following treatment on-site.	Partly. Reported as number of swimmers who had experienced symptoms before (not necessarily clinically diagnosed)	Not reported

Authors	Are the characteristics of the participants included in the study clearly defined?	Were the subjects who were prepared to participate representative of the entire population from which they were recruited? (selection bias)	Were the main outcome measures accurate (valid and reliable)? (measurement bias)		
			Short term outcomes i.e. hospitalisations and recovery	**Recurrence**	**Long term sequelae**
Ludwig et al. (2006)	Yes, 20 healthy fit military trainees aged 19-36 who had completed the first 5 weeks of a 22 week long Basic Underwater Demolition/SEAL training programme	Unclear, no demographic information on at risk population other than they are all male	Short term outcomes were not described, although all SIPE patients had recovered at least 4 weeks before study	Not reported	Partly. Measures of cardiopulmonary function compared to non-SIPE subjects
Adir et al. (2004)	Yes, 70 military trainees undergoing swimming time trials between 1998 and 2001 who were diagnosed with SIPE. All healthy fit males aged 18-19.	Yes, although the sample size is small, it is likely to be representative of the military trainee population in terms of age and sex	Yes, resolution of SIPE symptoms within 24 hours reported. Also included tests of lung function and echocardiographic investigations.	Yes, recurrences reported within 3 years of study	Not reported
Shupak et al. (2000)	Yes, 35 healthy fit military trainees undergoing swimming time trials over 2 months. All males aged 18-19.	Yes, although the sample size is small, it is likely to be representative of the military trainee population in terms of age and sex	Not reported	Yes, recurrences reported within the 2 months of the study	Not reported
Weiler-Ravell et al. (1995)	Yes, 30 healthy fit military trainees undergoing a swimming time trial. All males aged 18-19.	Yes, although the sample size is small, it is likely to be representative of the military trainee population in terms of age and sex	Yes, hospitalisations and resolution of SIPE symptoms within 24 hours reported	No, although recurrences reported during the remainder of the training programme, time lag is unknown.	Not reported

3e. Interventions

Authors	Are the characteristics of the participants included in the study clearly defined? (selection bias)	Were the subjects who were prepared to participate representative of the entire population from which they were recruited? (selection bias)	Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants? (selection bias)	Were the cases and controls/comparators recruited from the same population? (selection bias)	Were the main outcome measures accurate (valid and reliable)? (measurement bias)
Moon, Martina, Peacher, Potter, *et al.* (2016)	Yes, age, gender and exemptions described in detail	Unknown how SIPE subjects were chosen.	No. Body fat criterion not applicable to SIPE subjects and mild hypertension allowed in SIPE subjects if controlled by medication.	No sig diffs in age, BMI and race, but sig greater proportion of males in control group. IPE group may have been fitter than non-IPE group.	No. No untreated control group with a history of SIPE. Inconsistency in the way pre-exercise measurements were taken i.e. SIPE subjects were supine while non-SIPE subjects were sitting. No clinical outcomes reported.
Martina *et al.* (2017)	Yes, but only one participant.	N/A	N/A	N/A	No. Only one case so low quality study.

Appendix 4: Research Ethics Panel approval letters

4a. Ethical approval for development and validation of questionnaires

University of Kent | PSSRU

Personal Social Services
Research Unit

www.pssru.ac.uk

11 March 2019

TO WHOM IT MAY CONCERN

The SRC Ethics Panel of the University of Kent School of Social Policy, Sociology and Social Research has given the following project ethical approval:

Name of principal researcher: Sarah Spencer, CHSS
Title: The development and validation of two questionnaires to determine the occurrence and risk factors associated with swimming-induced pulmonary oedema [SRCEA id 223]
Date approval granted: 7 March 2019

Yours sincerely,

KJones

Dr Karen Jones
Chair
SRC Research Ethics Committee

The PSSRU conducts research and analysis on equity and efficiency in community care and related areas.

University of Kent
Cornwallis Building
Canterbury
Kent CT2 7NF
United Kingdom

4b. Ethical approval for occurrence and risk factor studies

28 June 2019

TO WHOM IT MAY CONCERN

The SRC Ethics Panel of the University of Kent School of Social Policy, Sociology and Social Research has given the following project ethical approval:

Name of principal researcher: Sarah Spencer
Title: How common is SIPE amongst competitors of open water swimming events in the UK and what are the risk factors? [SRCEA id 237]
Date approval granted: 28 June 2019

Yours sincerely,

KJones

Dr Karen Jones
Chair
SRC Research Ethics Committee

Appendix 5: Survey invitation examples

5a. Hever Castle Festival of Endurance

Email:

University of Kent is asking competitors of **outdoor swimming events** to take part in our short online post-race survey. The findings will help to develop guidance to improve the safety of outdoor swimmers. As a thank you, you will be entered in to a prize draw to win a **£100 Wiggle voucher.** Click here for further information and a link to the survey.

University of Kent

5b. London Triathlon

Facebook:

WIN a £100 Wiggle voucher

The University of Kent is asking competitors who are swimming at London Triathlon to take part in 2 short online surveys (http://bit.ly/Swimsurvey) on the health of outdoor swimmers. The findings will help to develop guidance to improve safety. As a thankyou, we'll enter you into our prize draws to win a £100 Wiggle voucher. To take part, click on the following links:

Pre-race survey (closes on 6th August): https://tinyurl.com/y3w58o3e

Post-race survey (27th July - 7th August): https://tinyurl.com/yyhu5uzk

Prize draws will take place on 12th August.

DRIVE.GOOGLE.COM

London triathlon outdoor swimmer survey flyer v2.pdf

Twitter:

Calling all competitors who are swimming at London Triathlon

WIN a £100 Wiggle voucher by completing 2 short online surveys as part of a University of Kent study on the health of outdoor swimmers. The findings will help to develop guidance to improve safety.

http://bit.ly/Swimsurvey

5c. Hever Castle Triathlon

Facebook:

Castle Race Series
9 October 2019 ·

Participate in research and win a £100 Wiggle voucher!
Did you swim at Hever Castle Triathlon? Please help the University of Kent PhD study on the health of outdoor swimmers by completing this short post-race survey:
https://tinyurl.com/yxmbo6o2
The findings will help develop safety guidance. Click here for further information:
http://bit.ly/heversurvey

Twitter:

Calling all Hever @CastleTriathlon swimmers!
WIN a £100 Wiggle voucher by completing a short survey for a @UniKent study on the health of outdoor swimmers. Findings will help develop safety guidance.
Pls RT! http://bit.ly/heversurvey

Calling all those who swam at Hever @CastleTriathlon!
WIN a £100 Wiggle voucher by completing a short survey for a @UniKent study on the health of outdoorswimmers. Findings will help develop safety guidance.
Pls RT! http://bit.ly/heversurvey

Invitation flyer:

5d. Outdoor Swimming Survey

Facebook:

Participate in research and win a £100 Wiggle voucher!
Do you swim outdoors in the UK? Please help the University of Kent PhD study on the health of outdoor swimmers by completing this short survey: http://bit.ly/swimsurvey20 The findings will help develop safety guidance. Click here for further information: http://bit.ly/swimsurvey-info

Twitter:

Participate in research and win a £100 Wiggle voucher!
Do you swim outdoors in the UK? Please help a @UniKent PhD study on the health of outdoor swimmers by completing a short survey. Findings will help develop safety guidance.
Pls RT! http://bit.ly/swimsurvey-info

Invitation flyer:

Appendix 6: Participant information sheets

6a. Questionnaire testing

CHSS
University of Kent
Centre for Health Services Studies

Development of two questionnaires for outdoor swimmers

Information for participants of questionnaire testing

Introduction
You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the project?
The research forms part of a PhD study on the health of outdoor swimmers. The purpose is to develop and test two questionnaires which will collect information on health conditions and breathing problems experienced by outdoor swimmers. We will be testing out the questions to ensure that they are understandable and collect the information we need. The questions will then be revised and used in a large survey of outdoor swimmers in the UK. Ultimately, the findings of the survey will help to develop guidance to improve the safety of outdoor swimmers.

Why have I been chosen?
Because you are someone who swims outdoors in the UK. We are recruiting swimmers and triathletes to test out our draft questionnaires to see if the questions make sense and provide us with the information we need for our research project.

Do I have to take part?
No. It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and you can still withdraw at any time without giving a reason.

What do I have to do?
We will email you a link to the two questionnaires plus an additional feedback questionnaire and ask you to complete them within three days. In total, the questionnaires should take no longer than 15 minutes to complete. This part of the research project is due to take place in March/April 2019.

What are the possible disadvantages and risks of taking part?
The questionnaires and feedback may take up to 15 minutes of your time.

What are the possible benefits of taking part?
You will receive a £5 Amazon eGift voucher by email to compensate for your time.

What happens to the information I give?
All the information that we collect about you during the course of the research will be kept strictly confidential. You will not be able to be identified in any reports or publications. The information will be used to make improvements to the questions ready for use in the survey.

What type of information will be sought from me and why is the collection of this information relevant for achieving the research project's objectives?
The questions will ask about experiences of open water swimming as well as any health conditions and medications being taken. We are testing out the questions and asking for feedback on them to ensure that they are understandable and collect the information we need. The questions will then be refined and used in a large health survey of outdoor swimmers in the UK.

Who is organising the research?
The research is being carried out and is partly funded by the University of Kent. The project has not received any external funding. An ethics committee at the University of Kent has reviewed the proposal and materials being used for this study.

What do I do now?
If you want to participate, please contact us directly by email using the contact details below and we will get in touch with you soon.

Who do I contact if I have questions about the study?
If you have further questions, or have any complaints about the conduct of this study, please contact Sarah Spencer (details below).

Thank you very much for your help.

Sarah Spencer
S.Spencer@kent.ac.uk
01227 827914

Main Supervisor:
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6b. Cognitive interviews

CHSS
University of Kent
Centre for Health Services Studies

Development of two questionnaires for outdoor swimmers

Information for interviewees

Introduction
You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the project?
The research forms part of a PhD study on the health of outdoor swimmers. The purpose is to develop and test two questionnaires which will collect information on health conditions and breathing problems experienced by outdoor swimmers. We will be carrying out interviews to ensure that they are clear and understandable, and collect the information we need. The questions will then be revised and used in a large survey of outdoor swimmers in the UK. Ultimately, the findings of the survey will help to develop guidance to improve the safety of outdoor swimmers.

Why have I been chosen?
Because you are someone who swims outdoors in the UK. We are recruiting swimmers and triathletes to interview as part of the testing of out our draft questionnaires to see if the questions make sense and provide us with the information we need for our research project.

Do I have to take part?
No. It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep (and be asked to sign a consent form) and you can still withdraw at any time without giving a reason.

What do I have to do?
We are asking if you would like to take part in an interview with a researcher at a venue of your choice, or over the telephone. During the interview we will go through the questionnaires orally, asking for feedback on the clarity and wording. The interview is likely to take between 30 minutes and 1 hour and will be audio recorded. This part of the research project is due to take place in March/April 2019.

What are the possible disadvantages and risks of taking part?
The interviews may take up to 1 hour of your time.

What are the possible benefits of taking part?
You will receive a £30 Amazon eGift voucher by email to compensate for your time.

What happens to the information I give?
All the information that we collect about you during the course of the research will be kept strictly confidential. When we have finished our interviews, we will write a report about the research process and our findings. We may include examples of what individuals have said, but we will never use any information that would identify those individuals. The information will be used to make improvements to the questions ready for use in the survey. Any interview transcripts and/or recordings will be securely stored for as long as is required by the Data Protection Act (1998) and then destroyed.

What type of information will be sought from me and why is the collection of this information relevant for achieving the research project's objectives?
The questions will ask about experiences of open water swimming as well as any health conditions and medications being taken. We are testing out the questions and asking for feedback on them to ensure that they are understandable and collect the information we need. The questions will then be refined and used in a large survey of outdoor swimmers in the UK.

Will I be recorded, and how will the recorded media be used?
The audio recordings made during this research will be transcribed and used only for analysis purposes only. No other use will be made of them without your written permission, and no one outside the project will be allowed access to the original recordings.

Who is organising the research?
The research is being carried out and is partly funded by the University of Kent. The project has not received any external funding. An ethics committee at the University of Kent has reviewed the proposal and materials being used for this study.

What do I do now?
If you want to participate, please contact us directly by email using the contact details below and we will get in touch with you soon.

Who do I contact if I have questions about the study?
If you have further questions, or have any complaints about the conduct of this study, please contact Sarah Spencer (details below).

Thank you very much for your help.

Sarah Spencer
S.Spencer@kent.ac.uk
01227 827914

Main Supervisor:
Dr Lindsay Forbes
L.Forbes@kent.ac.uk
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6c. Hever Castle Festival of Endurance pre-race survey

Hever Castle Festival of Endurance 2019
Pre-race survey – Information for participants

Introduction
You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. You can contact us by email or telephone (details overleaf) if there is anything that is not clear or if you would like more information.

What is the purpose of the project?
The purpose of the project is to collect information on the health of outdoor swimmers in the UK. We are carrying out two short online surveys: a pre-race survey and a post-race survey. Ultimately, the findings will help to develop guidance to improve the safety of outdoor swimmers.

Why have I been chosen?
Because you have entered an open water swimming event at Hever Castle Festival of Endurance.

Do I have to take part?
No. It is up to you to decide whether or not to take part. If you do decide to take part you will be asked if you agree to some consent statements before beginning the survey. Once you have started the survey you can still withdraw at any time by contacting us and we will ensure your data is deleted and not used in the study.

What do I have to do?
We are asking if you would like to take part in our short online pre-race survey by clicking the following link: https://kentsspssr.eu.qualtrics.com/jfe/form/SV_8iaza3z79YPqmAl. The survey will open on 1st July and will close on 15th July.

What are the possible disadvantages and risks of taking part?
The survey may take up to 10-15 minutes of your time.

What are the possible benefits of taking part?
If you provide an email address, you will be entered into a prize draw to win a £100 Wiggle voucher. The prize draw will take place on 16th July.

What happens to the information I give?
All the information that we collect about you will be kept strictly confidential. When we have finished the survey, we will write a report about the research process and our findings. You will not be able to be identified in any reports or publications.

What type of information will be sought from me?
The survey questions will ask about your experiences of open water swimming as well as any health conditions and medications being taken.

Who is organising the research?
The research is being carried out and is partly funded by the University of Kent. The project has not received any external funding. An ethics committee at the University of Kent has reviewed the proposal and materials being used for this study.

What do I do now?
If you want to participate, please click the following link:
https://kentsspssr.eu.qualtrics.com/jfe/form/SV_8iaza3z79YPqmAI

Who do I contact if I have questions about the study?
If you have further questions, or have any complaints about the conduct of this study, please contact Sarah Spencer (details below).

Thank you very much for your help.

Sarah Spencer
S.Spencer@kent.ac.uk
01227 827914

Main Supervisor:
Dr Lindsay Forbes
L.Forbes@kent.ac.ukj
01227 816440

Centre for Health Services Studies
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University of Kent
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Kent
CT2 7NF

Link to privacy statement
https://media.www.kent.ac.uk/se/5138/Research-privacy-notice-May-2019.pdf

6d. Hever Castle Festival of Endurance post-race survey

University of Kent Sport and Exercise Sciences

CHSS University of Kent Centre for Health Services Studies

Hever Castle Festival of Endurance 2019
Post-race survey – Information for participants

Introduction
You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. You can contact us by email or telephone (details overleaf) if there is anything that is not clear or if you would like more information.

What is the purpose of the project?
The purpose of the project is to collect information on the health of outdoor swimmers in the UK. We are carrying out two short online surveys: a pre-race survey and a post-race survey. Ultimately, the findings will help to develop guidance to improve the safety of outdoor swimmers.

Why have I been chosen?
Because you have entered an open water swimming event at Hever Castle Festival of Endurance.

Do I have to take part?
No. It is up to you to decide whether or not to take part. If you do decide to take part you will be asked if you agree to some consent statements before beginning the survey. Once you have started the survey you can still withdraw at any time by contacting us and we will ensure your data is deleted and not used in the study.

What do I have to do?
We are asking if you would like to take part in our short online post-race survey by clicking the following link: https://kentsspssr.eu.qualtrics.com/jfe/form/SV_cvUZkSaQakXPv13. The survey will open on **7th July** and will close on **21st July**.

What are the possible disadvantages and risks of taking part?
The survey may take up to 10-15 minutes of your time.

What are the possible benefits of taking part?
If you provide an email address, you will be entered into a prize draw to win a £100 Wiggle voucher. The prize draw will take place on 22nd July.

What happens to the information I give?
All the information that we collect about you will be kept strictly confidential. When we have finished the survey, we will write a report about the research process and our findings. You will not be able to be identified in any reports or publications.

What type of information will be sought from me?
The survey questions will ask about your recent experience of open water swimming at Hever Castle Festival of Endurance as well as any health conditions and medications being taken.

Who is organising the research?
The research is being carried out and is partly funded by the University of Kent. The project has not received any external funding. An ethics committee at the University of Kent has reviewed the proposal and materials being used for this study.

What do I do now?
If you want to participate, please click the following link **between the 7th and 21st July** (inclusive): https://kentsspssr.eu.qualtrics.com/jfe/form/SV_cvUZkSaQakXPv13

Who do I contact if I have questions about the study?
If you have further questions, or have any complaints about the conduct of this study, please contact Sarah Spencer (details below).

Thank you very much for your help.

Sarah Spencer S.Spencer@kent.ac.uk 01227 827914 Main Supervisor: Dr Lindsay Forbes L.Forbes@kent.ac.uk 01227 816440	Centre for Health Services Studies Cornwallis George Allen Wing University of Kent Canterbury Kent CT2 7NF

Link to privacy statement
https://media.www.kent.ac.uk/se/5138/Research-privacy-notice-May-2019.pdf

Appendix 7: Participant consent forms

CHSS
University of Kent
Centre for Health Services Studies

Sarah Spencer
Centre for Health Services Studies
University of Kent
George Allen Wing
Canterbury
Kent CT2 7NF
01227 827914

PARTICIPANT CONSENT FORM

Title of Project:	Development of two questionnaires for outdoor swimmers	**Ethics Approval Number:**	SRCEA id 223
Investigator(s):	Ms Sarah Spencer	**Researcher Email:**	S.Spencer@kent.ac.uk

Please tick the box if you agree with the statement

1.	I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.	☐
2.	I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my or my organisation's involvement in the project being affected in any way.	☐
3.	I give permission for members of the research team to have access to my responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. I understand that my responses will be kept strictly confidential.	☐
4.	I agree for the data collected from me to be stored and used in relevant future research in an anonymised form.	☐
5.	I understand that other genuine researchers will have access to this data only if they agree to preserve the confidentiality of the information as requested in this form.	
6.	I agree to take part in the above study and will inform the lead researcher should my contact details change.	☐

____________________	____________	____________
Name of Participant	Date	Signature
____________________	____________	____________
Researcher	Date	Signature

Please complete both copies of the consent form (keeping one for your own records).

Appendix 8: Pre-race questionnaire for online testing

Start of Block: Participant consent

C1 I confirm that I have read and understand the information sheet for the study and have had the opportunity to ask questions.

- ○ *Yes (1)*
- ○ *No (2)*

C2 I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

- ○ *Yes (1)*
- ○ *No (2)*

C3 I give permission for members of the research team to have access to my responses. I understand that I will not be identified or identifiable in the report or reports that result from the research. I understand that my responses will be kept strictly confidential.

- ○ *Yes (1)*
- ○ *No (2)*

C4 I agree for the data collected from me to be stored and used in relevant future research in an anonymised form.

- ○ *Yes (1)*
- ○ *No (2)*

C5 I confirm I am aged 18 or over and agree to take part in the above study.

- ○ *Yes (1)*
- ○ *No (2)*

Skip To: End of Survey If C5 = 2

C6 I consent to be re-contacted by researchers about possible future research related to the current study for which I may be eligible.

- ○ *Yes (1)*
- ○ *No (2)*

C7 Which race have you entered? (add options based on event)

____

End of Block: Participant consent

Start of Block: Case ascertainment

Q1.1 During or immediately after swimming, have you ever experienced an attack of shortness of breath that seemed out of proportion to the effort you were putting in?

○ *Yes (1)*

○ *No (2)*

Skip To: End of Block If 1.1 = 2

Q1.2 At the time of your most recent episode of breathlessness, do you believe it was caused by inhaling water?

○ *Yes (1)*

○ *No (2)*

Q1.3 At the time of your most recent episode of breathlessness, did the symptoms occur immediately on entering the water i.e. within seconds?

○ *Yes (1)*

○ *No (2)*

Q1.4 Was your most recent episode of breathlessness accompanied by any of the following symptoms? Tick all that apply.

- ☐ *Whistling or crackling sound in the chest (1)*
- ☐ *A cough not related to a cold or other respiratory infection (2)*
- ☐ *Coughing up phlegm or fluid (3)*
- ☐ *A feeling of tightness in your chest (4)*
- ☐ *Other: Please specify (5)* ____

Q1.5 Did a doctor tell you the breathlessness was due to any of the following? Tick all that apply.

- ☐ *Panic attack (1)*
- ☐ *Smoking (2)*
- ☐ *A nasal allergy i.e. hay fever (3)*
- ☐ *Asthma (including exercise-induced) (4)*
- ☐ *Pulmonary oedema (5)*
- ☐ *Pulmonary embolism (9)*
- ☐ *Heart failure (10)*
- ☐ *Other reason: please specify (11)* ____
- ☐ *⊗I did not seek medical advice (12)*

Display This Question:

If 1.5 = 12

Q1.5a Do you think the breathlessness was due to any of the following? Tick all that apply.

☐ *Panic attack (6)*

☐ *Smoking (9)*

☐ *A nasal allergy i.e. hay fever (10)*

☐ *Asthma (including exercise-induced) (11)*

☐ *Pulmonary oedema (12)*

☐ *Other reason: please specify (8)* ____

Q1.6 How many episodes of this breathlessness have you had?

○ *1 (1)*

○ *2 (2)*

○ *3 (3)*

○ *4 (4)*

○ *5 or more (5)*

Q1.7 What was your age when you first experienced these breathing problems?

○ *Under 20 (8)*

○ *20 - 29 (1)*

○ *30 - 39 (2)*

○ *40 - 49 (3)*

○ *50 - 59 (4)*

○ *60 - 69 (5)*

○ *70 or older (6)*

End of Block: Case ascertainment

Start of Block: Long Term Risk factors

Q2.1 In which months of the year have you participated in outdoor swimming in the UK? (Include training swims in your answer). Tick all that apply.

☐ *January (1)*

☐ *February (2)*

☐ *March (3)*

☐ *April (4)*

☐ *May (5)*

☐ *June (6)*

☐ *July (7)*

☐ *August (8)*

☐ *September (9)*

☐ *October (10)*

☐ *November (11)*

☐ *December (12)*

Q2.2 How many times have you been outdoor swimming in the UK in the last 12 months? (Include training swims in your answer).

○ *0 (1)*

○ *1 to 4 (2)*

○ *5 to 9 (3)*

○ *10 to 19 (4)*

○ *20 or more (5)*

Q2.3 Has a doctor diagnosed you with any of the following health conditions? Tick all that apply.

☐ *High blood pressure (1)*

☐ *Diabetes (2)*

☐ *Asthma (including exercise-induced) (3)*

☐ *Nasal allergy i.e. hay fever (4)*

☐ *Raynaud's syndrome (5)*

☐ *Heart failure or other heart trouble: Please specify (6)* ____

☐ *Other: Please specify (7)* ____

☐ *⊗No diagnosed health conditions (8)*

Q2.3a Do you think you have any of the following health conditions? Tick all that apply.

☐ *Asthma (including exercise-induced) (1)*

☐ *Nasal allergy i.e. hay fever (7)*

☐ *Raynaud's syndrome (8)*

☐ *Poor circulation (11)*

☐ *Other: Please specify (4)* ____

☐ *⊗No health conditions (10)*

Q2.4 Have you ever had any of the following? Tick all that apply.

☐ *Panic attack (1)*

☐ *Pulmonary oedema (2)*

☐ *Pulmonary embolism (3)*

☐ *Angina (4)*

☐ *Pneumonia (5)*

☐ *⊗None of the above (6)*

Q2.5 On most days over the last 3 months, did you take any regular medication or nutritional supplements?

◯ *Yes: Please specify which medications and/or supplements (1)* ____

◯ *No (2)*

Q2.6 Which one of these best describes you?

◯ *I have never smoked (1)*

◯ *I used to smoke occasionally but do not smoke at all now (2)*

◯ *I used to smoke daily but do not smoke at all now (3)*

◯ *I smoke occasionally but not every day (4)*

◯ *I smoke daily (5)*

Display This Question:

If 2.6 = 2

And 2.6 = 3

Q52 How long ago did you stop smoking?

____

Q2.7 How often have you had an alcoholic drink of any kind during the last 12 months?

◯ *Never (1)*

◯ *Monthly or less (2)*

◯ *Two to four times per month (3)*

◯ *Two to three times per week (4)*

◯ *Four or more times per week (5)*

Skip To: End of Block If 2.7 = 1

Q2.8 During the last 12 months, how many alcoholic drinks did you have on a typical day when you drank alcohol?

◯ *1 to 2 (1)*

◯ *3 to 4 (2)*

◯ *5 to 6 (3)*

◯ *7 to 9 (4)*

◯ *10 or more (5)*

End of Block: Long Term Risk factors

Start of Block: Demographics

Q3.1 How old are you?

○ *Under 20 (8)*

○ *20 - 29 (1)*

○ *30 - 39 (2)*

○ *40 - 49 (3)*

○ *50 - 59 (4)*

○ *60 - 69 (5)*

○ *70 or older (6)*

Q3.2 What is your gender?

○ *Male (1)*

○ *Female (2)*

Q3.3 How tall are you without shoes? You can enter it in metres or in feet and inches.

○ *Metres: (1)* ____________________

○ *Feet and inches: (2)* ____________________

Q3.4 Which of these ethnic groups do you consider you belong to?

◯ *White (1)*

◯ *Mixed (2)*

◯ *Asian or Asian British (3)*

◯ *Black or Black British (4)*

◯ *Chinese or other ethnic group (5)*

Q3.5 How much do you weigh without clothes and shoes? You can enter it in kilograms or in stone and pounds.

◯ *Kilograms: (1)* ____

◯ *Stone and pounds: (2)* ____

◯ *Pounds: (8)* ____

Q3.6 Which region do you currently live in?

▼ South East (7) ... Outside the UK (14)

End of Block: Demographics

Appendix 9: Post-race questionnaire for online testing

Start of Block: Default Question Block

Q1.0 Please provide your email address so we can send your voucher to you.

____

IMPORTANT: The following questions refer to a "recent triathlon event". Please answer them as if they were asking about your most recent outdoor swim in the UK.

Q1.1 During or immediately after your recent swim at the triathlon event, did you experience an attack of shortness of breath that seemed out of proportion to the effort you were putting in?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If During or immediately after your recent swim at the triathlon event, did you experience an attack... = Yes

Q1.2 Do you believe it was caused by breathing in water?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If During or immediately after your recent swim at the triathlon event, did you experience an attack... = Yes

Q1.3 Did the symptoms occur immediately on entering the water i.e. within seconds?

- Yes (1)
- No (2)

Display This Question:

If During or immediately after your recent swim at the triathlon event, did you experience an attack... = Yes

Q1.4 Was this shortness of breath accompanied by any of the following symptoms? Please tick all that apply.

- *Whistling or crackling sound in the chest (1)*
- *A cough not related to a cold or other respiratory infection (2)*
- *Coughing up phlegm or fluid (3)*
- *A feeling of tightness in your chest (4)*
- *Other: Please specify (5)* ____

Display This Question:

If During or immediately after your recent swim at the triathlon event, did you experience an attack... = Yes

Q1.5 Did a doctor tell you or do you think that the breathlessness was due to any of the following? Tick all that apply.

☐ *Panic attack (1)*

☐ *Smoking (2)*

☐ *A nasal allergy i.e. hay fever (3)*

☐ *Asthma (4)*

☐ *Pulmonary oedema (5)*

☐ *Pulmonary embolism (6)*

☐ *Heart failure (7)*

☐ *Other reason: Please specify (8)* ____

End of Block: Default Question Block

Start of Block: Block 4

Display This Question:

If During or immediately after your recent swim at the triathlon event, did you experience an attack... = Yes

Q2.1 Following your most recent episode of breathlessness, did you seek medical advice?

○ Yes (1)

○ No (2)

Display This Question:

If Following your most recent episode of breathlessness, did you seek medical advice? = Yes

Q2.3 What treatment did you receive?

☐ *No treatment (observation only) (1)*

☐ *Diuretic (2)*

☐ *Oxygen (3)*

☐ *Inhaler (4)*

☐ *Other: Please specify (5)* ____

☐ *Not sure (6)*

Display This Question:

If Following your most recent episode of breathlessness, did you seek medical advice? = Yes

Q2.4 Where were you observed or treated medically? Tick all that apply.

☐ *On site (swim exit, medical tent etc.) (1)*

☐ *Ambulance (2)*

☐ *Hospital (3)*

☐ *Other healthcare facility (clinic, GP surgery etc): Please specify (4)*
____

Display This Question:

If Where were you observed or treated medically? Tick all that apply. = Hospital

Q2.5 Where in hospital were you observed or treated? Tick all that apply.

☐ *A&E (1)*

☐ *Outpatient clinic (2)*

☐ *Admitted to a hospital ward (3)*

Display This Question:

If Where in hospital were you observed or treated? Tick all that apply. = Admitted to a hospital ward

Q2.6 How long did you stay in hospital?

◯ Less than a day (no overnight stay) (1)

◯ 1 night (2)

◯ 2 nights (3)

◯ 3 or more nights (4)

End of Block: Block 4

Start of Block: Block 3

Q3.1 What distance was your swim at your recent triathlon event?

◯ less than 500 metres (1)

◯ 500-1000 metres (2)

◯ 1001-2000 metres (3)

◯ 2001-3000 metres (4)

◯ greater than 3000 metres (5)

Q3.2 If known, please state the temperature of the water during your swim in degrees Celsius.

____

Q3.3 Did you wear a wetsuit?

- ◯ Yes (1)
- ◯ No (2)

Q3.4 How much did you drink in the hour prior to swimming, based on a regular bike size (600-900 litre capacity) bottle?

- ◯ Less than half a bottle (1)
- ◯ Half to one bottle (2)
- ◯ Greater than one bottle (3)

Q3.5 Did you spend time warming up in the water immediately before the start of the swim?

- ◯ Yes (1)
- ◯ No (2)

Q3.6 Did you get very nervous or anxious at any time during the swim?

◯ Yes (1)

◯ No (2)

Q3.7 What level of effort did you put into swimming?

◯ Minimal (1)

◯ Moderate (not exhausting) (2)

◯ Strenuous (3)

End of Block: Block 3

Appendix 10: Feedback questionnaire

Start of Block: Default Question Block

Q0.1 Please provide your email address.

____

Q1 Overall, how easy to understand did you find the questions?

- ◯ Extremely easy (1)
- ◯ Somewhat easy (2)
- ◯ Neither easy nor difficult (3)
- ◯ Somewhat difficult (4)
- ◯ Extremely difficult (5)

Q2 Please tell us about any questions you found difficult to understand.

____

____

____

____

____

Q3 Did any of the questions make you feel uncomfortable?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q3 = Yes

Q4 Please tell us about the question(s) that made you feel uncomfortable.

____

____

____

____

____

Q5 Were you able to answer all the questions asked?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q5 = No

Q6 Please tell us about any questions that you had difficulty answering.

____

____

____

____

____

Q7 How do you feel about the length of the questionnaires?

- ◯ Too long (1)
- ◯ About the right length (2)
- ◯ Too short (3)

Q8 Please use the space below to add any further comments you may have on the questionnaires.

____

____

____

____

____

End of Block: Default Question Block

Appendix 11: Cognitive interview schedule

The purpose of the cognitive interview is to determine if the questions are interpreted in the way intended and to detect where the wording and/or response options may be difficult to understand or ambiguous.

The interviewer will go through each individual question in the pre- and post-race questionnaires and will ask the interviewee to 'think aloud' whilst they answer the questions. The interviewer will also use verbal probes, for example:

- What were you thinking of when you answered the question?
- I noticed you were spending some time thinking about that question – can you tell me what you were thinking about?
- I noticed you hesitated before you answered – what were you thinking about?
- What were you basing your answer on?
- Were any parts of the question confusing or difficult to understand?
- Was that easy or difficult to answer? Why was that?
- How did you feel about answering this question?
- Were the response options appropriate?

Pre-amble for interview

Thanks for agreeing to take part in the interview. As you know, I'm a researcher from CHSS at the University of Kent. Before we start, I just want to explain what we are doing here today. As I said in the email, I am preparing a new survey, but before I start, I am testing out the questions to ensure that they are understandable and collect the information I need.

The research forms part of my PhD study on the health of outdoor swimmers. I am developing and testing two questionnaires which will collect information on competitors of triathlons and open water swimming events this year. The first questionnaire will be carried in the week before the race and the second one in the days following the race.

Do you have any questions on the study before I talk about the interview?

Let me explain a little bit more about how the interview will work. I'm going to read you some questions. When you hear a question, I want you to say out loud, the thoughts that come into your mind. This is called 'thinking aloud'. We've found that it helps to have some practice at doing this. So let me give you an example:

Let's say I was asked a question about "how many windows are there in my house". If I was thinking aloud, I would say "…Well, there's one window in the kitchen…And then in the living room there are two windows…and so on."

Now let me ask you the same question: "Think about how many windows there are in your house. As you count up the windows, tell me what you are seeing and thinking about."

I would like to record the interview (show recorder), because this saves me having to take detailed notes and I can pay full attention to what you are saying. Do I have your permission to use the recorder?

START RECORDER

Appendix 12: Expert review form

Validating a questionnaire to identify swimming induced pulmonary oedema – Expert review

We have developed a questionnaire for outdoor swimmers, to identify episodes of swimming induced pulmonary oedema (SIPE) and collect data on risk factors. We are currently doing some validation studies, one of which involves collecting, systematically, the views of clinical and epidemiological experts on how well the questionnaire will identify cases of SIPE and relevant risk factors. We are very grateful for your help on this – we hope it will not take you more than 20 minutes.

Instructions

First, please complete a short checklist[6] for each of the 9 questionnaire items. The checklist is a prompt to help you identify and articulate any problems, to avoid your having to put much thought into the quality of each question (pages 2-12). Please select yes or no for each item (by clicking on the box) and please write notes too if you feel it would be useful. (NB the questionnaire will also include some questions about health behaviours and demographics that we have not included in this, because we will be using questions that have been validated elsewhere.)

Second, please give us your opinions on how we are going to define SIPE (page 13).

We would be very grateful if you could complete and return this by Wednesday 26th June.

Thank you very much for your help.

[6] Checklist based on Willis, G. and Lessler, J. (1999) Questionnaire Appraisal System-1999, Research Triangle Park, NC: Research Triangle Institute

Question 1 During or immediately after swimming, have you ever experienced an attack of shortness of breath that seemed out of proportion to the effort you were putting in?

- Yes
- No

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.		
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes	☐ No
Describe any problems here.		
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.		
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes	☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes	☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes	☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes	☐ No
Describe any problems here.		
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.		
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes	☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes	☐ No
Describe any problems here.		
4. KNOWLEDGE/MEMORY: Check whether respondents are likely to not know or have trouble remembering information.		
KNOWLEDGE may not exist: Respondent is unlikely to know the answer to a factual question.	☐ Yes	☐ No
ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes	☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes	☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes	☐ No
Describe any problems here.		
5. SENSITIVITY/BIAS: Assess questions for sensitive nature or wording, and for bias.		
SENSITIVE CONTENT (general): The question asks about a topic that is embarrassing, very private, or that involves illegal behaviour.	☐ Yes	☐ No
SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes	☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes	☐ No
Describe any problems here.		
6. RESPONSE CATEGORIES: Assess the adequacy of the range of responses to be recorded.		
OPEN-ENDED QUESTION that is inappropriate or difficult.	☐ Yes	☐ No
MISMATCH between question and response categories.	☐ Yes	☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes	☐ No
VAGUE response categories are subject to multiple interpretations.	☐ Yes	☐ No
OVERLAPPING response categories.	☐ Yes	☐ No
MISSING eligible responses in response categories.	☐ Yes	☐ No
ILLOGICAL ORDER of response categories	☐ Yes	☐ No
Describe any problems here.		
7. OTHER PROBLEMS		
Other problems not previously identified.	☐ Yes	☐ No
Describe any problems here.		

Question 2 At the time of your most recent episode of breathlessness, do you believe it was caused by inhaling water?

- Yes
- No

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.	
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes ☐ No
Describe any problems here.	
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.	
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes ☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes ☐ No
Describe any problems here.	
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.	
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes ☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes ☐ No
Describe any problems here.	
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ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes ☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes ☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes ☐ No
Describe any problems here.	
5. SENSITIVITY/BIAS: Assess questions for sensitive nature or wording, and for bias.	
SENSITIVE CONTENT (general): The question asks about a topic that is embarrassing, very private, or that involves illegal behaviour.	☐ Yes ☐ No
SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes ☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes ☐ No
Describe any problems here.	
6. RESPONSE CATEGORIES: Assess the adequacy of the range of responses to be recorded.	
OPEN-ENDED QUESTION that is inappropriate or difficult.	☐ Yes ☐ No
MISMATCH between question and response categories.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE response categories are subject to multiple interpretations.	☐ Yes ☐ No
OVERLAPPING response categories.	☐ Yes ☐ No
MISSING eligible responses in response categories.	☐ Yes ☐ No
ILLOGICAL ORDER of response categories	☐ Yes ☐ No
Describe any problems here.	
7. OTHER PROBLEMS	
Other problems not previously identified.	☐ Yes ☐ No
Describe any problems here.	

Question 3 At the time of your most recent episode of breathlessness, did the symptoms occur immediately on entering the water i.e. within seconds?

- Yes
- No

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.	
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes ☐ No
Describe any problems here.	
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.	
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes ☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes ☐ No
Describe any problems here.	
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.	
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes ☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes ☐ No
Describe any problems here.	
4. KNOWLEDGE/MEMORY: Check whether respondents are likely to not know or have trouble remembering information.	
KNOWLEDGE may not exist: Respondent is unlikely to know the answer to a factual question.	☐ Yes ☐ No
ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes ☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes ☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes ☐ No
Describe any problems here.	
5. SENSITIVITY/BIAS: Assess questions for sensitive nature or wording, and for bias.	
SENSITIVE CONTENT (general): The question asks about a topic that is embarrassing, very private, or that involves illegal behaviour.	☐ Yes ☐ No
SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes ☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes ☐ No
Describe any problems here.	
6. RESPONSE CATEGORIES: Assess the adequacy of the range of responses to be recorded.	
OPEN-ENDED QUESTION that is inappropriate or difficult.	☐ Yes ☐ No
MISMATCH between question and response categories.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE response categories are subject to multiple interpretations.	☐ Yes ☐ No
OVERLAPPING response categories.	☐ Yes ☐ No
MISSING eligible responses in response categories.	☐ Yes ☐ No
ILLOGICAL ORDER of response categories	☐ Yes ☐ No
Describe any problems here.	
7. OTHER PROBLEMS	
Other problems not previously identified.	☐ Yes ☐ No
Describe any problems here.	

Question 4 Was your most recent episode of breathlessness accompanied by any of the following symptoms? Tick all that apply.

- Whistling or crackling sound in the chest
- A cough not related to a cold or other respiratory infection
- Coughing up phlegm or fluid
- A feeling of tightness in your chest
- Other: Please specify

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.		
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes	☐ No
Describe any problems here.		
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.		
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes	☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes	☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes	☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes	☐ No
Describe any problems here.		
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.		
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes	☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes	☐ No
Describe any problems here.		
4. KNOWLEDGE/MEMORY: Check whether respondents are likely to not know or have trouble remembering information.		
KNOWLEDGE may not exist: Respondent is unlikely to know the answer to a factual question.	☐ Yes	☐ No
ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes	☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes	☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes	☐ No
Describe any problems here.		
5. SENSITIVITY/BIAS: Assess questions for sensitive nature or wording, and for bias.		
SENSITIVE CONTENT (general): The question asks about a topic that is embarrassing, very private, or that involves illegal behaviour.	☐ Yes	☐ No
SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes	☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes	☐ No
Describe any problems here.		
6. RESPONSE CATEGORIES: Assess the adequacy of the range of responses to be recorded.		
OPEN-ENDED QUESTION that is inappropriate or difficult.	☐ Yes	☐ No
MISMATCH between question and response categories.	☐ Yes	☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes	☐ No
VAGUE response categories are subject to multiple interpretations.	☐ Yes	☐ No
OVERLAPPING response categories.	☐ Yes	☐ No
MISSING eligible responses in response categories.	☐ Yes	☐ No
ILLOGICAL ORDER of response categories	☐ Yes	☐ No
Describe any problems here.		
7. OTHER PROBLEMS		
Other problems not previously identified.	☐ Yes	☐ No
Describe any problems here.		

Question 5 Did a doctor tell you or did you think the breathlessness was due to any of the following? Tick all that apply.

	Medical diagnosis	Self-diagnosis
Panic attack	☐	☐
Smoking	☐	☐
A nasal allergy i.e. hay fever	☐	☐
Asthma (including exercise-induced)	☐	☐
Cold shock response	☐	☐
Pulmonary oedema or SIPE	☐	☐
Pulmonary embolism	☐	☐
Heart failure	☐	☐

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.	
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes ☐ No
Describe any problems here.	
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.	
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes ☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes ☐ No
Describe any problems here.	
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.	
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes ☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes ☐ No
Describe any problems here.	
4. KNOWLEDGE/MEMORY: Check whether respondents are likely to not know or have trouble remembering information.	
KNOWLEDGE may not exist: Respondent is unlikely to know the answer to a factual question.	☐ Yes ☐ No
ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes ☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes ☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes ☐ No
Describe any problems here.	
5. SENSITIVITY/BIAS: Assess questions for sensitive nature or wording, and for bias.	
SENSITIVE CONTENT (general): The question asks about a topic that is embarrassing, very private, or that involves illegal behaviour.	☐ Yes ☐ No
SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes ☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes ☐ No
Describe any problems here.	
6. RESPONSE CATEGORIES: Assess the adequacy of the range of responses to be recorded.	
OPEN-ENDED QUESTION that is inappropriate or difficult.	☐ Yes ☐ No
MISMATCH between question and response categories.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE response categories are subject to multiple interpretations.	☐ Yes ☐ No
OVERLAPPING response categories.	☐ Yes ☐ No
MISSING eligible responses in response categories.	☐ Yes ☐ No
ILLOGICAL ORDER of response categories	☐ Yes ☐ No

Describe any problems here.	
7. OTHER PROBLEMS	
Other problems not previously identified.	☐ Yes ☐ No
Describe any problems here.	

Question 6 How many episodes of this breathlessness have you had?

- 1
- 2
- 3
- 4
- 5 or more

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.	
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes ☐ No
Describe any problems here.	
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.	
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes ☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes ☐ No
Describe any problems here.	
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.	
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes ☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes ☐ No
Describe any problems here.	
4. KNOWLEDGE/MEMORY: Check whether respondents are likely to not know or have trouble remembering information.	
KNOWLEDGE may not exist: Respondent is unlikely to know the answer to a factual question.	☐ Yes ☐ No
ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes ☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes ☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes ☐ No
Describe any problems here.	
5. SENSITIVITY/BIAS: Assess questions for sensitive nature or wording, and for bias.	
SENSITIVE CONTENT (general): The question asks about a topic that is embarrassing, very private, or that involves illegal behaviour.	☐ Yes ☐ No
SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes ☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes ☐ No
Describe any problems here.	
6. RESPONSE CATEGORIES: Assess the adequacy of the range of responses to be recorded.	
OPEN-ENDED QUESTION that is inappropriate or difficult.	☐ Yes ☐ No
MISMATCH between question and response categories.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE response categories are subject to multiple interpretations.	☐ Yes ☐ No
OVERLAPPING response categories.	☐ Yes ☐ No
MISSING eligible responses in response categories.	☐ Yes ☐ No
ILLOGICAL ORDER of response categories	☐ Yes ☐ No
Describe any problems here.	
7. OTHER PROBLEMS	
Other problems not previously identified.	☐ Yes ☐ No
Describe any problems here.	

Question 7 Do you currently have any of the following health conditions? Tick all that apply.

	Medical diagnosis	Self-diagnosis
High blood pressure	☐	☐
Diabetes	☐	☐
Asthma (including exercise-induced)	☐	☐
Nasal allergy i.e. hay fever	☐	☐
Raynaud's disease	☐	☐
Heart failure or other heart trouble: Please specify	☐	☐
Other: Please specify	☐	☐
No health conditions	☐	☐

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.		
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes	☐ No
Describe any problems here.		
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.		
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes	☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes	☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes	☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes	☐ No
Describe any problems here.		
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.		
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes	☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes	☐ No
Describe any problems here.		
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KNOWLEDGE may not exist: Respondent is unlikely to know the answer to a factual question.	☐ Yes	☐ No
ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes	☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes	☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes	☐ No
Describe any problems here.		
5. SENSITIVITY/BIAS: Assess questions for sensitive nature or wording, and for bias.		
SENSITIVE CONTENT (general): The question asks about a topic that is embarrassing, very private, or that involves illegal behaviour.	☐ Yes	☐ No
SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes	☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes	☐ No
Describe any problems here.		
6. RESPONSE CATEGORIES: Assess the adequacy of the range of responses to be recorded.		
OPEN-ENDED QUESTION that is inappropriate or difficult.	☐ Yes	☐ No
MISMATCH between question and response categories.	☐ Yes	☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes	☐ No
VAGUE response categories are subject to multiple interpretations.	☐ Yes	☐ No
OVERLAPPING response categories.	☐ Yes	☐ No
MISSING eligible responses in response categories.	☐ Yes	☐ No
ILLOGICAL ORDER of response categories	☐ Yes	☐ No

Describe any problems here.	
7. OTHER PROBLEMS	
Other problems not previously identified.	☐ Yes ☐ No
Describe any problems here.	

Question 8 Have you ever had any of the following? Tick all that apply.

- Panic attack
- Pulmonary oedema
- Pulmonary embolism
- Angina
- Pneumonia
- None of the above

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.	
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes ☐ No
Describe any problems here.	
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.	
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes ☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes ☐ No
Describe any problems here.	
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.	
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes ☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes ☐ No
Describe any problems here.	
4. KNOWLEDGE/MEMORY: Check whether respondents are likely to not know or have trouble remembering information.	
KNOWLEDGE may not exist: Respondent is unlikely to know the answer to a factual question.	☐ Yes ☐ No
ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes ☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes ☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes ☐ No
Describe any problems here.	
5. SENSITIVITY/BIAS: Assess questions for sensitive nature or wording, and for bias.	
SENSITIVE CONTENT (general): The question asks about a topic that is embarrassing, very private, or that involves illegal behaviour.	☐ Yes ☐ No
SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes ☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes ☐ No
Describe any problems here.	
6. RESPONSE CATEGORIES: Assess the adequacy of the range of responses to be recorded.	
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MISMATCH between question and response categories.	☐ Yes ☐ No
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VAGUE response categories are subject to multiple interpretations.	☐ Yes ☐ No
OVERLAPPING response categories.	☐ Yes ☐ No
MISSING eligible responses in response categories.	☐ Yes ☐ No
ILLOGICAL ORDER of response categories	☐ Yes ☐ No
Describe any problems here.	
7. OTHER PROBLEMS	
Other problems not previously identified.	☐ Yes ☐ No
Describe any problems here.	

Question 9 On most days over the last 3 months, did you take any regular medication or nutritional supplements?

- Yes: Please specify which medications and/or supplements
- No

1. INSTRUCTIONS: Look for problems with any introductions, instructions or explanations.	
CONFLICTING, INACCURATE OR COMPLICATED INSTRUCTIONS, introductions, or explanations	☐ Yes ☐ No
Describe any problems here.	
2. CLARITY: Identify problems related to communicating the intent or meaning of the question to the respondent.	
WORDING: Question is lengthy, awkward, ungrammatical, or contains complicated syntax.	☐ Yes ☐ No
TECHNICAL TERM(S) are undefined, unclear, or complex.	☐ Yes ☐ No
VAGUE: There are multiple ways to interpret the question or to decide what is to be included or excluded.	☐ Yes ☐ No
REFERENCE PERIODS are missing, not well specified, or in conflict.	☐ Yes ☐ No
Describe any problems here.	
3. ASSUMPTIONS: Determine if there are problems with assumptions made or the underlying logic.	
ASSUMES CONSTANT BEHAVIOUR or experience for situations that vary.	☐ Yes ☐ No
DOUBLE-BARRELED: Contains more than one implicit question.	☐ Yes ☐ No
Describe any problems here.	
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KNOWLEDGE may not exist: Respondent is unlikely to know the answer to a factual question.	☐ Yes ☐ No
ATTITUDE may not exist: Respondent is unlikely to have formed the attitude being asked about.	☐ Yes ☐ No
RECALL failure: Respondent may not remember the information asked for.	☐ Yes ☐ No
COMPUTATION problem: The question requires a difficult mental calculation.	☐ Yes ☐ No
Describe any problems here.	
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SENSITIVE WORDING (specific): Given that the general topic is sensitive, the wording should be improved to minimize sensitivity.	☐ Yes ☐ No
SOCIALLY ACCEPTABLE response is implied by the question.	☐ Yes ☐ No
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MISMATCH between question and response categories.	☐ Yes ☐ No
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VAGUE response categories are subject to multiple interpretations.	☐ Yes ☐ No
OVERLAPPING response categories.	☐ Yes ☐ No
MISSING eligible responses in response categories.	☐ Yes ☐ No
ILLOGICAL ORDER of response categories	☐ Yes ☐ No
Describe any problems here.	
7. OTHER PROBLEMS	
Other problems not previously identified.	☐ Yes ☐ No
Describe any problems here.	

Identifying possible cases of SIPE

We propose defining people as having possible SIPE if they say YES to the question about having an attack of SOB out of proportion to the effort and either

a. A doctor has told them that it was due to pulmonary oedema or SIPE
   OR
b. They do not believe it was caused by inhaling water AND it did not occur immediately on entering the water

based on their responses to these questions:

During or immediately after swimming, have you ever experienced an attack of shortness of breath that seemed out of proportion to the effort you were putting in? *Required response = YES* **AND** Did a doctor tell you or do you think that the breathlessness was due to any of the following? *Required response = Pulmonary oedema or SIPE* **OR** During or immediately after swimming, have you ever experienced an attack of shortness of breath that seemed out of proportion to the effort you were putting in? *Required response = YES* **AND** At the time of your most recent episode of breathlessness, do you believe it was caused by inhaling water? *Required response = NO* **AND** At the time of your most recent episode of breathlessness, did the symptoms occur immediately on entering the water i.e. within seconds? *Required response = NO*

Please use the space below to let us know your views on this way of identifying possible cases of SIPE

Appendix 13: Final pre-race questionnaire

Start of Block: Information for participants

Q121 Please read the following information before you begin the survey. **What is the purpose of the project?** We are collecting information on the health of outdoor swimmers in the UK through two surveys; a pre-race and post-race survey. This pre-race survey is open to all competitors who will be swimming at Hever Castle Triathlon. The findings will help to develop guidance to improve the safety of outdoor swimmers. **Do I have to take part?** No. Participation is voluntary. If you decide to take part you will be asked if you agree to some consent statements before beginning the survey. Once you have started the survey you can still withdraw at any time by contacting us and we will ensure your data is deleted and not used in the study. **What are the possible disadvantages of taking part?** The survey may take up to 10 minutes of your time. **What are the possible benefits of taking part?** You will be entered into a prize draw to win a **£100 Wiggle voucher**. The survey will open on **26th August** and close on **29th September.** The prize draw will take place on 1st October. **What happens to the information I give?** All the information that we collect about you will be kept strictly confidential. When we have finished the survey, we will write a report about the research process and our findings. You will not be identifiable in any reports or publications. **What type of information will be sought from me?** The survey questions will ask about your experiences of open water swimming as well as any health conditions and medications being taken. **Who is organising the research?** The research is being carried out and is partly funded by the University of Kent. The project has not received any external funding. An ethics committee at the University of Kent has reviewed the proposal and materials being used for this study. **Contact details** If you have further questions, or have any complaints about the conduct of this study, please contact Sarah Spencer at **s.spencer@kent.ac.uk** or **01227 827914**. **Thank you very much for your help.** *Link to privacy statement https://media.www.kent.ac.uk/se/5138/Research-privacy-notice-May-2019.pdf*

End of Block: Information for participants

Start of Block: Participant consent

*

QID55 Please tick the box if you agree with the statement.

○ I confirm that I have read and understand the information sheet for the study. (5)

○ I understand that my participation is voluntary and that I am free to withdraw at any time. (4)

○ I give permission for members of the research team to have access to my responses. I understand that my responses will be kept strictly confidential and I will not be identifiable in any reports that result from the research. (6)

○ I confirm I am aged 18 or over and agree to take part in the study. (7)

○ I consent to being contacted by researchers as part of this study or future related research. (8)

○ I agree for the data collected from me to be stored and used in relevant future research in an anonymised form. (9)

QID63 Please provide an email address so we can enter you into the prize draw.

____

QID65 Which race have you entered at Hever Castle Triathlon?

- ◯ Starter Tri - Castle Tri (200m/15km/2km) (20)
- ◯ Super Sprint - Anne Boleyn (400m/20km/4km) (12)
- ◯ Sprint (750m/20km/5km) (11)
- ◯ Sprint Plus - Henry VIII (800m/40km/8km) (10)
- ◯ Olympic / Standard - The Hever (1.5km/40km/10km) (26)
- ◯ Half Iron / Middle Distance - The Gauntlet (1.9km/90km/21km) (25)
- ◯ Aquabike Sprint (Swim 750m/Bike 20km) (23)
- ◯ Aquabike Standard (Swim 1500m/Bike 40km) (27)
- ◯ Aquathlon Sprint (Swim 750m/Run 5km) (24)
- ◯ Aquathlon Standard (Swim 1500m/Run 10km) (28)
- ◯ Hever Outdoor Swimmer (5km) (13)
- ◯ Hever Outdoor Swimmer (2.5km) (21)
- ◯ Hever Outdoor Swimmer (1 mile) (22)

End of Block: Participant consent

Start of Block: Case ascertainment

QID1 Have you ever had shortness of breath during or straight after swimming outdoors that was out of proportion to the effort you were putting in?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If Have you ever had shortness of breath during or straight after swimming outdoors that was out of... = Yes

QID2 The next few questions are about **<u>the last time</u>** you had shortness of breath during or straight after swimming outdoors, that was out of proportion to the effort you were putting in.
Do you believe it was caused by inhaling water?

◯ Yes (1)

◯ No (2)

◯ Partly: Please give details (5) ____

◯ Don't know (6)

Display This Question:

If Have you ever had shortness of breath during or straight after swimming outdoors that was out of... = Yes

QID3 When did the shortness of breath start?

◯ Immediately (within seconds of entering the water) (1)

◯ Later during the swim (3)

◯ After the swim (4)

Display This Question:

If Have you ever had shortness of breath during or straight after swimming outdoors that was out of... = Yes

QID4 Did you have any other symptoms at the time? Tick all that apply.

- ☐ Wheezing or whistling in the chest (1)
- ☐ Crackling sound in the chest (6)
- ☐ An unexplained cough (2)
- ☐ Coughing up phlegm, froth or fluid (3)
- ☐ A feeling of tightness in your chest (4)
- ☐ Other: Please specify (5) ____
- ☐ ⊗No other symptoms (7)

Display This Question:

If Did you have any other symptoms at the time? Tick all that apply. = Coughing up phlegm, froth or fluid

Q67 What colour was the phlegm, froth or fluid?

- ○ Yellow (1)
- ○ White (2)
- ○ Brown (3)
- ○ Pink, red or blood stained (4)
- ○ Other: Please specify (5) ____
- ○ Don't know (6)

Display This Question:

If Have you ever had shortness of breath during or straight after swimming outdoors that was out of... = Yes

QID5 Do you think the shortness of breath was due to any of the following? Tick all that apply.

☐ Panic attack (1)

☐ Smoking (2)

☐ Allergies such as hay fever (3)

☐ Cold shock response (4)

☐ Other reason: please specify (11) ____

☐ ⊗None of the above (13)

Display This Question:

If Do you think the shortness of breath was due to any of the following? Tick all that apply. = Panic attack

QID53 You selected panic attack. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

○ Yes (6)

○ No (13)

Display This Question:

If You selected panic attack. Did you see any health professional (e.g. doctor, nurse, paramedic) ab... = Yes

Q68 Did they think the shortness of breath was due to a panic attack?

○ Yes (1)

○ No (2)

Display This Question:

If Do you think the shortness of breath was due to any of the following? Tick all that apply. = Smoking

Q73 You selected smoking. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If Do you think the shortness of breath was due to any of the following? Tick all that apply. = Smoking

Q74 Did they think the shortness of breath was due to smoking?

◯ Yes (1)

◯ No (2)

Display This Question:

If Do you think the shortness of breath was due to any of the following? Tick all that apply. = Allergies such as hay fever

Q75 You selected allergies such as hay fever. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If You selected allergies such as hay fever. Did you see any health professional (e.g. doctor, nurse... = Yes

Q76 Did they think the shortness of breath was due to allergies such as hay fever?

◯ Yes (1)

◯ No (2)

Display This Question:

If Do you think the shortness of breath was due to any of the following? Tick all that apply. = Cold shock response

Q77 You selected cold shock response. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

○ Yes (1)

○ No (2)

Display This Question:

If You selected cold shock response. Did you see any health professional (e.g. doctor, nurse, parame... = Yes

Q78 Did they think the shortness of breath was due to cold shock response?

○ Yes (1)

○ No (2)

Display This Question:

If Do you think the shortness of breath was due to any of the following? Tick all that apply. = Other reason: please specify

Q79 You selected other reason: ${QID5/ChoiceTextEntryValue/11}. Did you see any health professional (e.g. doctor, nurse, paramedic) about this ?

○ Yes (1)

○ No (2)

Display This Question:

If You selected other reason: ${q://QID5/ChoiceTextEntryValue/11}. Did you see any health profession... = Yes

Q72 Did they think the shortness of breath was due to ${QID5/ChoiceTextEntryValue/11}?

◯ Yes (1)

◯ No (2)

Display This Question:

If Have you ever had shortness of breath during or straight after swimming outdoors that was out of... = Yes

Q69 Has a health professional ever diagnosed you with any of the following health conditions?

☐ Asthma (1)

☐ Chronic bronchitis (3)

☐ COPD (chronic obstructive pulmonary disease) (2)

☐ Emphysema (5)

☐ Heart condition: please specify (4) ____

☐ Pulmonary embolism (blood clot in the lung) (6)

☐ Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs) (7)

☐ High blood pressure (10)

☐ Diabetes (11)

☐ Pneumonia (13)

☐ Other: please specify (8) ____

☐ ⊗ None of the above (9)

Display This Question:

If Have you ever had shortness of breath during or straight after swimming outdoors that was out of... = No

Q117 Has a health professional ever diagnosed you with any of the following health conditions?

☐ Asthma (1)

☐ Chronic bronchitis (2)

☐ COPD (chronic obstructive pulmonary disease) (3)

☐ Emphysema (4)

☐ Heart condition: please specify (5) ____

☐ Pulmonary embolism (blood clot in the lung) (6)

☐ Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs) (7)

☐ High blood pressure (15)

☐ Diabetes (13)

☐ Pneumonia (11)

☐ Other: please specify (8) ____

☐ ⊗None of the above (16)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Asthma

Q70 Do you think the shortness of breath was due to asthma?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Asthma

Q71 Did a health professional think it was due to asthma?

- Yes (1)
- No (2)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Chronic bronchitis

Q81 Do you think the shortness of breath was due to chronic bronchitis?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Chronic bronchitis

Q101 Did a health professional think it was due to chronic bronchitis?

- Yes (1)
- No (2)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = COPD (chronic obstructive pulmonary disease)

Q82 Do you think the shortness of breath was due to COPD (chronic obstructive pulmonary disease)?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = COPD (chronic obstructive pulmonary disease)

Q94 Did a health professional think it was due to COPD?

- Yes (1)
- No (2)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Emphysema

Q83 Do you think the shortness of breath was due to emphysema?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Emphysema

Q95 Did a health professional think it was due to emphysema?

- Yes (1)
- No (2)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Heart condition: please specify

Q84 Do you think the shortness of breath was due to a heart condition?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Heart condition: please specify

Q96 Did a health professional think it was due to a heart condition?

◯ Yes (1)

◯ No (2)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Pulmonary embolism (blood clot in the lung)

Q85 Do you think the shortness of breath was due to a pulmonary embolism (blood clot in the lung)?

◯ Yes (1)

◯ No (2)

◯ Partly (5)

◯ Don't know (6)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Pulmonary embolism (blood clot in the lung)

Q97 Did a health professional think it was due to a pulmonary embolism?

◯ Yes (1)

◯ No (2)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs)

Q86 Do you think the shortness of breath was due to pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs)?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs)

Q98 Did a health professional think it was due to pulmonary oedema or swimming induced pulmonary oedema?

- Yes (1)
- No (2)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Other: please specify

Q103 Do you think the shortness of breath was due to ${Q69/ChoiceTextEntryValue/8}?

- Yes (1)
- No (2)
- Partly (4)
- Don't know (5)

Display This Question:

If Has a health professional ever diagnosed you with any of the following health conditions? = Other: please specify

Q99 Did a health professional think it was due to this?

◯ Yes (1)

◯ No (2)

Display This Question:

If Have you ever had shortness of breath during or straight after swimming outdoors that was out of... = Yes

QID6
Now we are going back to talk about **all episodes** of shortness of breath you have experienced during or after swimming outdoors, that seemed out of proportion to the effort you were putting in.

How many episodes of this type of shortness of breath have you had?

◯ 1 (1)

◯ 2 (2)

◯ 3 (3)

◯ 4 (4)

◯ 5 or more (5)

Display This Question:

If Have you ever had shortness of breath during or straight after swimming outdoors that was out of... = Yes

QID7 What was your age when you first experienced this type of shortness of breath?

- ○ Under 20 (8)
- ○ 20 - 29 (1)
- ○ 30 - 39 (2)
- ○ 40 - 49 (3)
- ○ 50 - 59 (4)
- ○ 60 - 69 (5)
- ○ 70 or older (6)

End of Block: Case ascertainment

Start of Block: Long Term Risk factors

QID11 In which months of the year have you done outdoor swimming in the UK? (Include training swims in your answer). Tick all that apply.

- ☐ January (1)
- ☐ February (2)
- ☐ March (3)
- ☐ April (4)
- ☐ May (5)
- ☐ June (6)
- ☐ July (7)
- ☐ August (8)
- ☐ September (9)
- ☐ October (10)
- ☐ November (11)
- ☐ December (12)

QID12 How many times have you been outdoor swimming in the UK in the last 12 months? (Include training swims in your answer).

- ◯ 0 (1)
- ◯ 1 to 4 (2)
- ◯ 5 to 9 (3)
- ◯ 10 to 19 (4)
- ◯ 20 or more (5)

QID8 Do you think you have ever had symptoms of any of the following health conditions? Tick all that apply.

- ☐ Asthma (including exercise induced) (15)
- ☐ Allergies such as hay fever (16)
- ☐ Raynaud's disease (reduced blood flow to fingers and toes in response to cold) (3)
- ☐ Panic attack (9)
- ☐ ⊗ None of the above (8)

Display This Question:

If Do you think you have ever had symptoms of any of the following health conditions? Tick all that... = Allergies such as hay fever

QID51 You selected allergies such as hay fever. Was this confirmed by a health professional?

- ◯ Yes (1)
- ◯ No (12)

Display This Question:

If Do you think you have ever had symptoms of any of the following health conditions? Tick all that... = Raynaud's disease (reduced blood flow to fingers and toes in response to cold)

Q105 You selected Raynaud's disease. Was this confirmed by a health professional?

◯ Yes (1)

◯ No (12)

Display This Question:

If Do you think you have ever had symptoms of any of the following health conditions? Tick all that... = Panic attack

Q104 You selected panic attack. Was this confirmed by a health professional?

◯ Yes (1)

◯ No (12)

QID10 On most days over the last 3 months, did you take any regular medication or nutritional supplements?

◯ Yes: Please specify which medications and/or supplements e.g. aspirin, multivitamins (1) ____

◯ No (2)

QID32 Which one of these best describes you?

◯ I have never smoked (1)

◯ I used to smoke occasionally but do not smoke at all now (2)

◯ I used to smoke daily but do not smoke at all now (3)

◯ I smoke occasionally but not every day (4)

◯ I smoke daily (5)

Display This Question:

If Which one of these best describes you? = I used to smoke occasionally but do not smoke at all now

Or Which one of these best describes you? = I used to smoke daily but do not smoke at all now

QID52 How long ago did you stop smoking?

____

QID31 How often have you had an alcoholic drink of any kind during the last 12 months?

◯ Never (1)

◯ Monthly or less (2)

◯ Two to four times per month (3)

◯ Two to three times per week (4)

◯ Four or more times per week (5)

Skip To: End of Block If How often have you had an alcoholic drink of any kind during the last 12 months? = Never

QID33 During the last 12 months, how many alcoholic drinks did you have on a typical day when you drank alcohol?

◯ 1 to 2 (1)

◯ 3 to 4 (2)

◯ 5 to 6 (3)

◯ 7 to 9 (4)

◯ 10 or more (5)

End of Block: Long Term Risk factors

Start of Block: Demographics

QID13 How old are you?

◯ Under 20 (8)

◯ 20 - 29 (1)

◯ 30 - 39 (2)

◯ 40 - 49 (3)

◯ 50 - 59 (4)

◯ 60 - 69 (5)

◯ 70 or older (6)

QID14 What is your gender?

◯ Male (1)

◯ Female (2)

QID22 How tall are you without shoes? You can enter it in metres or in feet and inches.

◯ Metres: (1) ____

◯ Feet and inches: (2) ____

QID16 Which of these ethnic groups do you consider you belong to?

◯ White (1)

◯ Mixed (2)

◯ Asian or Asian British (3)

◯ Black or Black British (4)

◯ Chinese or other ethnic group (5)

◯ Prefer not to say (6)

QID17 How much do you weigh without clothes and shoes? You can enter it in kilograms or in stone and pounds.

◯ Kilograms: (1) ____

◯ Stone and pounds: (2) ____

◯ Pounds: (8) ____

QID18 Which region do you currently live in?

- South East (7)
- South West (8)
- London (4)
- West Midlands (9)
- East Midlands (2)
- East of England (3)
- Yorkshire and The Humber (10)
- North East (5)
- North West (6)
- Wales (11)
- Scotland (12)
- N Ireland (13)
- Outside the UK (14)

Q119 Please use to space below to tell us anything further you would like to say about any of the issues raised in the questionnaire.

____

____

____

____

____

End of Block: Demographics

Appendix 14: Final post-race questionnaire

Start of Block: Information for participants

Q136 Please read the following information before you begin the survey. **What is the purpose of the project?** We are collecting information on the health of outdoor swimmers in the UK through two surveys; a pre-race and post-race survey. This post-race survey is open to all competitors aged 18+ who swam at Hever Castle Triathlon. The findings will help to develop guidance to improve the safety of outdoor swimmers. **Do I have to take part?** No. Participation is voluntary. If you decide to take part you will be asked if you agree to some consent statements before beginning the survey. Once you have started the survey you can still withdraw at any time by contacting us and we will ensure your data is deleted and not used in the study.

What are the possible disadvantages of taking part? The survey may take up to 10 minutes of your time. **What are the possible benefits of taking part?** You will be entered into a prize draw to win a **£100 Wiggle voucher**. The survey will will open on **28th September** and close on **21st October**. The prize draw will take place on 22nd October. **What happens to the information I give?** All the information that we collect about you will be kept strictly confidential. When we have finished the survey, we will write a report about the research process and our findings. You will not be identifiable in any reports or publications. **What type of information will be sought from me?** The survey questions will ask about your experiences of open water swimming as well as any health conditions and medications being taken. **Who is organising the research?** The research is being carried out and is partly funded by the University of Kent. The project has not received any external funding. An ethics committee at the University of Kent has reviewed the proposal and materials being used for this study. **Contact details**If you have further questions, or have any complaints about the conduct of this study, please contact Sarah Spencer at **s.spencer@kent.ac.uk** or **01227 827914**.

Thank you very much for your help.

Link to privacy statement https://media.www.kent.ac.uk/se/5138/Research-privacy-notice-May-2019.pdf

End of Block: Information for participants

Start of Block: Block 1

QID46 Please tick the box if you agree with the statement.

☐ I confirm that I have read and understand the information sheet for the study. (5)

☐ I understand that my participation is voluntary and that I am free to withdraw at any time. (4)

☐ I give permission for members of the research team to have access to my responses. I understand that my responses will be kept strictly confidential and I will not be identifiable in any reports that result from the research. (6)

☐ I confirm I am aged 18 or over and agree to take part in the study. (7)

☐ I consent to being contacted by researchers as part of this study or future related research. (8)

☐ I agree for the data collected from me to be stored and used in relevant future research in an anonymised form. (9)

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*

QID47 Please provide an email address so we can enter you into the prize draw.

____

Q139 Which race were you in at Hever Castle Triathlon?

- ◯ Starter Tri - Castle Tri (200m/15km/2km) (20)
- ◯ Super Sprint - Anne Boleyn (400m/20km/4km) (12)
- ◯ Sprint (750m/20km/5km) (11)
- ◯ Sprint Plus - Henry VIII (800m/40km/8km) (10)
- ◯ Olympic / Standard - The Hever (1.5km/40km/10km) (26)
- ◯ Half Iron / Middle Distance - The Gauntlet (1.9km/90km/21km) (25)
- ◯ Aquabike Sprint (Swim 750m/Bike 20km) (23)
- ◯ Aquabike Standard (Swim 1500m/Bike 40km) (27)
- ◯ Aquathlon Sprint (Swim 750m/Run 5km) (24)
- ◯ Aquathlon Standard (Swim 1500m/Run 10km) (28)
- ◯ Hever Outdoor Swimmer (5km) (13)
- ◯ Hever Outdoor Swimmer (2.5km) (21)
- ◯ Hever Outdoor Swimmer (1 mile) (22)

End of Block: Block 1

Start of Block: Block 2

QID1 During or straight after your swim at Hever Castle Triathlon, did you have shortness of breath that was out of proportion to the effort you were putting in?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If QID1 = 1

QID2 The next few questions are about the shortness of breath you had during or straight after swimming at Hever Castle Triathlon.
Do you believe the shortness of breath was caused by inhaling water?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Partly: Please give details (3) ____
- ◯ Don't know (4)

Display This Question:

If QID1 = 1

QID3 When did the shortness of breath start?

- ◯ Immediately (within seconds of entering the water) (1)
- ◯ Later during the swim (3)
- ◯ After the swim (4)

Display This Question:

If QID1 = 1

QID17 Did you have any other symptoms at the time? Tick all that apply.

- ☐ Wheezing or whistling in the chest (1)
- ☐ Crackling sound in the chest (6)
- ☐ An unexplained cough (2)
- ☐ Coughing up phlegm, froth or fluid (3)
- ☐ A feeling of tightness in your chest (4)
- ☐ Other: Please specify (5) ____
- ☐ ⊗ No other symptoms (7)

Display This Question:

If QID17 = 3

QID88 What colour was the phlegm, froth or fluid?

- ○ Yellow (1)
- ○ White (2)
- ○ Brown (3)
- ○ Pink, red or blood stained (4)
- ○ Other: Please specify (5) ____
- ○ Don't know (6)

Display This Question:

If QID1 = 1

QID89 Do you think the shortness of breath was due to any of the following? Tick all that apply.

- [ ] Panic attack (1)
- [ ] Smoking (2)
- [ ] Allergies such as hay fever (3)
- [ ] Cold shock response (4)
- [ ] Other reason: please specify (11) ____
- [ ] ⊗None of the above (13)

Display This Question:

If QID89 = 1

QID90 You selected panic attack. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

- ○ Yes (6)
- ○ No (13)

Display This Question:

If QID90 = 6

QID91 Did they think the shortness of breath was due to a panic attack?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If QID89 = 2

QID92 You selected smoking. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID92 = 1

QID93 Did they think the shortness of breath was due to smoking?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID89 = 3

QID94 You selected allergies such as hay fever. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID95 = 1

QID95 Did they think the shortness of breath was due to allergies such as hay fever?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID89 = 4

QID96 You selected cold shock response. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

○ Yes (1)

○ No (2)

Display This Question:

If QID96 = 1

QID97 Did they think the shortness of breath was due to cold shock response?

○ Yes (1)

○ No (2)

Display This Question:

If QID89 = 11

QID98 You selected other reason: ${QID89/ChoiceTextEntryValue/11}. Did you see any health professional (e.g. doctor, nurse, paramedic) about this ?

○ Yes (1)

○ No (2)

Display This Question:

If QID98 = 1

QID99 Did they think the shortness of breath was due to ${QID89/ChoiceTextEntryValue/11}?

○ Yes (1)

○ No (2)

Display This Question:

If QID1 = 1

QID100 Has a health professional ever diagnosed you with any of the following health conditions?

☐ Asthma (1)

☐ Chronic bronchitis (3)

☐ COPD (chronic obstructive pulmonary disease) (2)

☐ Emphysema (5)

☐ Heart condition: please specify (4)
____

☐ Pulmonary embolism (blood clot in the lung) (6)

☐ Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs) (7)

☐ High blood pressure (10)

☐ Diabetes (11)

☐ Pneumonia (13)

☐ Other: please specify (8) ____

☐ ⊗None of the above (9)

Display This Question:

If QID1 = 2

QID101 Has a health professional ever diagnosed you with any of the following health conditions?

☐ Asthma (1)

☐ Chronic bronchitis (2)

☐ COPD (chronic obstructive pulmonary disease) (3)

☐ Emphysema (4)

☐ Heart condition: please specify (5) ____

☐ Pulmonary embolism (blood clot in the lung) (6)

☐ Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs) (7)

☐ High blood pressure (15)

☐ Diabetes (13)

☐ Pneumonia (11)

☐ Other: please specify (8) ____

☐ ⊗None of the above (16)

Display This Question:

If QID100 = 1

QID102 Do you think the shortness of breath was due to asthma?

◯ Yes (1)

◯ No (2)

◯ Partly (5)

◯ Don't know (6)

Display This Question:

If QID100 = 1

QID103 Did a health professional think it was due to asthma?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID100 = 3

QID104 Do you think the shortness of breath was due to chronic bronchitis?

◯ Yes (1)

◯ No (2)

◯ Partly (5)

◯ Don't know (6)

Display This Question:

If QID100 = 3

QID105 Did a health professional think it was due to chronic bronchitis?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If QID100 = 2

QID106 Do you think the shortness of breath was due to COPD (chronic obstructive pulmonary disease)?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Partly (5)
- ◯ Don't know (6)

Display This Question:

If QID100 = 2

QID107 Did a health professional think it was due to COPD?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If QID100 = 5

QID108 Do you think the shortness of breath was due to emphysema?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If QID100 = 5

QID109 Did a health professional think it was due to emphysema?

- Yes (1)
- No (2)

Display This Question:

If QID100 = 4

QID110 Do you think the shortness of breath was due to a heart condition?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If QID100 = 4

QID111 Did a health professional think it was due to a heart condition?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID100 = 6

QID112 Do you think the shortness of breath was due to a pulmonary embolism (blood clot in the lung)?

◯ Yes (1)

◯ No (2)

◯ Partly (5)

◯ Don't know (6)

Display This Question:

If QID100 = 6

QID113 Did a health professional think it was due to a pulmonary embolism?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID100 = 7

QID114 Do you think the shortness of breath was due to pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs)?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If QID100 = 7

QID115 Did a health professional think it was due to pulmonary oedema or swimming induced pulmonary oedema?

- Yes (1)
- No (2)

Display This Question:

If QID100 = 8

QID116 Do you think the shortness of breath was due to ${QID100/ChoiceTextEntryValue/8}?

- Yes (1)
- No (2)
- Partly (4)
- Don't know (5)

Display This Question:

If QID100 = 8

QID117 Did a health professional think it was due to this?

◯ Yes (1)

◯ No (2)

End of Block: Block 2

Start of Block: Block 3

QID118 Did you complete your swim at Hever Castle Triathlon?

◯ Yes (1)

◯ No: Please estimate how far you swam (2) ____

Display This Question:

If QID1 = 1

QID31 Did you receive any medical attention following the shortness of breath you had during or straight after swimming at Hever Castle Triathlon?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID31 = 1

QID42 How soon after the shortness of breath started did you receive medical attention?

◯ Immediately (1)

◯ Less than 2 hours (2)

◯ 2 - 11 hours (3)

◯ 12 - 24 hours (6)

◯ More than 24 hours (7)

Display This Question:

If QID31 = 1

QID33 What kind of medical attention did you receive? Tick all that apply.

▢ Observation only (1)

▢ Oxygen (3)

▢ Inhaler (4)

▢ Diuretics (8)

▢ Diagnostic tests e.g. x-ray, ultrasound scan, ECG (electrocardiogram), echocardiogram. Please specify (7) ____

▢ Other: Please specify (5) ____

▢ ⊗Don't know (6)

Display This Question:

If QID31 = 1

QID34 Where did you receive medical attention? Tick all that apply.

☐ On site (swim exit, medical tent etc.) (1)

☐ Ambulance (2)

☐ Hospital (3)

☐ Other healthcare facility e.g. clinic, GP surgery etc. Please specify (4) ____

Display This Question:

If QID34 = 3

QID35 Where in hospital did you receive medical attention? Tick all that apply.

☐ A&E (1)

☐ Admitted to a hospital ward (3)

☐ Outpatient clinic (2)

☐ Other: Please specify (5) ____

☐ ⊗Don't know (4)

Display This Question:

If QID35 = 3

QID36 How long did you stay in hospital?

○ Less than a day (no overnight stay) (1)

○ 1 night (2)

○ 2 nights (3)

○ 3 or more nights (4)

End of Block: Block 3

Start of Block: Block 4

*

QID22 If known, please state the temperature of the water during your swim in degrees Celsius.

____

QID23 Did you wear a wetsuit?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID23 = 1

QID121 What kind of wetsuit was it?

◯ Full length (1)

◯ Shorty (2)

Display This Question:

If QID23 = 1

QID122 What kind of sleeves did the wetsuit have?

◯ Long sleeves (1)

◯ Short sleeves (2)

◯ Sleeveless (3)

Display This Question:

If QID23 = 1

QID123 Did the wetsuit feel very tight or restrictive?

◯ Yes (1)

◯ No (2)

QID124 Did you have anything to drink in **the hour** prior to swimming?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID124 = 1

QID125 What did you drink?

☐ Water (4)

☐ Sports drink (5)

☐ Tea/coffee (1)

☐ Other: Please specify (2) ____

Display This Question:

If QID124 = 1

Q125 In total, how much did you drink in **<u>the hour</u>** before swimming, based on a regular bike size (500-750 ml capacity) bottle?

◯ Less than half a bottle (1)

◯ Half to one bottle (2)

◯ Greater than one bottle (3)

QID26 Did you spend time warming up in the water immediately before the start of the swim?

◯ Yes (1)

◯ No (2)

QID28 Did you get very nervous or anxious at any time during the swim?

◯ Yes: Please give details (1) ____

◯ No (2)

QID29 Please rate the **maximum** level of effort you put into your swim at London Triathlon, ranging from 0% (no effort at all) to 100% (maximum effort).

- 0-9% (12)
- 10-19% (17)
- 20-29% (13)
- 30-39% (14)
- 40-49% (15)
- 50-59% (19)
- 60-69% (16)
- 70-79% (18)
- 80-89% (20)
- 90-100% (21)

End of Block: Block 4

Start of Block: Block 4

QID87 Have you completed our pre-race survey?

- Yes (1)
- No (2)

Skip To: End of Survey If QID87 = 1

Q140 Prior to Hever Castle Triathlon, did you ever have shortness of breath during or straight after swimming outdoors that was out of proportion to the effort you were putting in?

- Yes (1)
- No (2)

Display This Question:

If Q140 = 1

Q142 The next few questions are about the **last time** you experienced shortness of breath (before Hever Castle Triathlon), during or straight after swimming outdoors, that was out of proportion to the effort you were putting in.
Do you believe it was caused by inhaling water?

- ◯ Yes (1)
- ◯ No (2)
- ◯ Partly: Please give details (5) ____
- ◯ Don't know (6)

Display This Question:

If Q140 = 1

Q144 When did the shortness of breath start?

- ◯ Immediately (within seconds of entering the water) (1)
- ◯ Later during the swim (3)
- ◯ After the swim (4)

Display This Question:

If Q140 = 1

Q146 Did you have any other symptoms at the time? Tick all that apply.

☐ Wheezing or whistling in the chest (1)

☐ Crackling sound in the chest (6)

☐ An unexplained cough (2)

☐ Coughing up phlegm, froth or fluid (3)

☐ A feeling of tightness in your chest (4)

☐ Other: Please specify (5) ____

☐ ⊗No other symptoms (7)

Display This Question:

If Q146 = 3

Q148 What colour was the phlegm, froth or fluid?

○ Yellow (1)

○ White (2)

○ Brown (3)

○ Pink, red or blood stained (4)

○ Other: Please specify (5) ____

○ Don't know (6)

Display This Question:

If Q140 = 1

Q150 Do you think the shortness of breath was due to any of the following? Tick all that apply.

- ☐ Panic attack (1)
- ☐ Smoking (2)
- ☐ Allergies such as hay fever (3)
- ☐ Cold shock response (4)
- ☐ Other reason: please specify (11) ____
- ☐ ⊗None of the above (13)

Display This Question:

If Q150 = 1

Q152 You selected panic attack. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

- ○ Yes (6)
- ○ No (13)

Display This Question:

If Q152 = 6

Q154 Did they think the shortness of breath was due to a panic attack?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Q150 = 2

Q156 You selected smoking. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q156 = 1

Q158 Did they think the shortness of breath was due to smoking?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q150 = 3

Q160 You selected allergies such as hay fever. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q160 = 1

Q162 Did they think the shortness of breath was due to allergies such as hay fever?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q150 = 4

Q164 You selected cold shock response. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

- Yes (1)
- No (2)

Display This Question:

If Q164 = 1

Q166 Did they think the shortness of breath was due to cold shock response?

- Yes (1)
- No (2)

Display This Question:

If Q150 = 11

Q168 You selected other reason: ${Q150/ChoiceTextEntryValue/11}. Did you see any health professional (e.g. doctor, nurse, paramedic) about this ?

- Yes (1)
- No (2)

Display This Question:

If Q168 = 1

Q170 Did they think the shortness of breath was due to ${Q150/ChoiceTextEntryValue/11}?

- Yes (1)
- No (2)

Display This Question:

If Q140 = 1

Q208
How many episodes of this type of shortness of breath have you had?

- ◯ 1 (1)
- ◯ 2 (2)
- ◯ 3 (3)
- ◯ 4 (4)
- ◯ 5 or more (5)

Display This Question:

If Q140 = 1

Q210 What was your age when you first experienced this type of shortness of breath?

- ◯ Under 20 (8)
- ◯ 20 - 29 (1)
- ◯ 30 - 39 (2)
- ◯ 40 - 49 (3)
- ◯ 50 - 59 (4)
- ◯ 60 - 69 (5)
- ◯ 70 or older (6)

QID72 In which months of the year have you participated in outdoor swimming in the UK? (Include training swims in your answer). Tick all that apply.

- ☐ January (1)
- ☐ February (2)
- ☐ March (3)
- ☐ April (4)
- ☐ May (5)
- ☐ June (6)
- ☐ July (7)
- ☐ August (8)
- ☐ September (9)
- ☐ October (10)
- ☐ November (11)
- ☐ December (12)

QID73 How many times have you been outdoor swimming in the UK in the last 12 months? (Include training swims in your answer).

- ○ 0 (1)
- ○ 1 to 4 (2)
- ○ 5 to 9 (3)
- ○ 10 to 19 (4)
- ○ 20 or more (5)

Q131 Do you think you have ever had symptoms of any of the following health conditions? Tick all that apply.

☐ Asthma (including exercise induced) (15)

☐ Allergies such as hay fever (16)

☐ Raynaud's disease (reduced blood flow to fingers and toes in response to cold) (3)

☐ Panic attack (9)

☐ ⊗None of the above (8)

Display This Question:

If Q131 = 16

Q133 You selected allergies such as hay fever. Was this confirmed by a health professional?

○ Yes (1)

○ No (12)

Display This Question:

If Q131 = 3

Q135 You selected Raynaud's disease. Was this confirmed by a health professional?

○ Yes (1)

○ No (12)

Display This Question:

If Q131 = 9

Q137 You selected panic attack. Was this confirmed by a health professional?

◯ Yes (1)

◯ No (12)

QID76 On most days over the last 3 months, did you take any regular medication or nutritional supplements?

◯ Yes: Please specify which medications and/or supplements e.g aspirin, multivitamins (1) ____

◯ No (2)

QID77 Which one of these best describes you?

◯ I have never smoked (1)

◯ I used to smoke occasionally but do not smoke at all now (2)

◯ I used to smoke daily but do not smoke at all now (3)

◯ I smoke occasionally but not every day (4)

◯ I smoke daily (5)

Display This Question:

If QID77 = 2

Or QID77 = 3

QID78 How long ago did you stop smoking?

____

QID79 How often have you had an alcoholic drink of any kind during the last 6 months?

○ Never (1)

○ Monthly or less (2)

○ Two to four times per month (3)

○ Two to three times per week (4)

○ Four or more times per week (5)

Display This Question:

If QID79 = 2

Or QID79 = 3

Or QID79 = 4

Or QID79 = 5

QID80 During the last 6 months, how many alcoholic drinks did you have on a typical day when you drank alcohol?

○ 1 to 2 (1)

○ 3 to 4 (2)

○ 5 to 6 (3)

○ 7 to 9 (4)

○ 10 or more (5)

End of Block: Block 4

Start of Block: Block 6

QID81 How old are you?

○ Under 20 (8)

○ 20 - 29 (1)

○ 30 - 39 (2)

○ 40 - 49 (3)

○ 50 - 59 (4)

○ 60 - 69 (5)

○ 70 or older (6)

QID82 What is your gender?

○ Male (1)

○ Female (2)

QID83 How tall are you without shoes? You can enter it in metres or in feet and inches.

○ Metres: (1) ____

○ Feet and inches: (2) ____

QID84 Which of these ethnic groups do you consider you belong to?

- ○ White (1)
- ○ Mixed (2)
- ○ Asian or Asian British (3)
- ○ Black or Black British (4)
- ○ Chinese or other ethnic group (5)
- ○ Prefer not to say (6)

QID85 How much do you weigh without clothes and shoes? You can enter it in kilograms, stone or pounds.

- ○ Kilograms: (1) ____
- ○ Stone and pounds: (2) ____
- ○ Pounds: (8) ____

QID86 Which region do you currently live in?

- South East (7)
- South West (8)
- London (4)
- West Midlands (9)
- East Midlands (2)
- East of England (3)
- Yorkshire and The Humber (10)
- North East (5)
- North West (6)
- Wales (11)
- Scotland (12)
- N Ireland (13)
- Outside the UK (14)

End of Block: Block 6

Appendix 15: Outdoor swimming questionnaire

Start of Block: Information for participants

Q136 Please read the following information before you begin the survey. **What is the purpose of the project?** We are collecting information on the health of outdoor swimmers in the UK through an online survey. The survey is open to adults who swim outdoors in the UK who have not already completed any of our outdoor swimmer surveys. The findings will help to develop guidance to improve the safety of outdoor swimmers. **Do I have to take part?** No. Participation is voluntary. If you decide to take part you will be asked if you agree to some consent statements before beginning the survey. Once you have started the survey you can still withdraw at any time by contacting us and we will ensure your data is deleted and not used in the study.

What are the possible disadvantages of taking part? The survey may take up to 10 minutes of your time. **What are the possible benefits of taking part?** You will be entered into a prize draw to win **one of four £100 Wiggle vouchers**. The survey opens on **5th February** and closes on **30th March.** The prize draw will take place on **31st March**. **What happens to the information I give?** All the information that we collect about you will be kept strictly confidential. When we have finished the survey, we will write a report about the research process and our findings. You will not be identifiable in any reports or publications. **What type of information will be sought from me?** The survey questions will ask about your experiences of open water swimming as well as any health conditions and medications being taken. **Who is organising the research?** The research is being carried out and is partly funded by the University of Kent. The project has not received any external funding. An ethics committee at the University of Kent has reviewed the proposal and materials being used for this study. **Contact details**If you have further questions, or have any complaints about the conduct of this study, please contact Sarah Spencer at **s.spencer@kent.ac.uk** or **01227 827914**.

Thank you very much for your help.
Link to privacy statement https://www.kent.ac.uk/chss/contact/privacy.html

End of Block: Information for participants

Start of Block: Consent

*

QID46 Please tick the box if you agree with the statement.

☐ I confirm that I have read and understand the information sheet for the study. (5)

☐ I understand that my participation is voluntary and that I am free to withdraw at any time. (4)

☐ I give permission for members of the research team to have access to my responses. I understand that my responses will be kept strictly confidential and I will not be identifiable in any reports that result from the research. (6)

☐ I confirm I am aged 18 or over and agree to take part in the study. (7)

☐ I consent to being contacted by researchers as part of this study or future related research. (8)

☐ I agree for the data collected from me to be stored and used in relevant future research in an anonymised form. (9)

QID47 Please provide an email address so we can enter you into the prize draw.

____

End of Block: Consent

Start of Block: Case ascertainment

Q140 Have you ever had shortness of breath during or straight after swimming outdoors that was out of proportion to the effort you were putting in?

○ Yes (1)

○ No (2)

Display This Question:

If Q140 = 1

Q208
How many episodes of this type of shortness of breath have you had?

○ 1 (1)

○ 2 (2)

○ 3 (3)

○ 4 (4)

○ 5 or more (5)

Display This Question:

If Q140 = 1

Q186 What was your age when you first experienced this type of shortness of breath?

○ Under 20 (8)

○ 20 - 29 (1)

○ 30 - 39 (2)

○ 40 - 49 (3)

○ 50 - 59 (4)

○ 60 - 69 (5)

○ 70 or older (6)

Display This Question:

If Q140 = 1

Q179 When was the last time you experienced this type of shortness of breath?

◯ Last year (2019) (1)

◯ 2-3 years ago (2017-18) (4)

◯ 4-5 years ago (2015-16) (7)

◯ Over 5 years ago (pre-2015) (5)

◯ Other: Please specify (8) ____

◯ Don't know (9)

Display This Question:

If Q140 = 1

Q142 The next few questions are about the **last time** you experienced shortness of breath during or straight after swimming outdoors, that was out of proportion to the effort you were putting in.
Do you believe it was caused by inhaling water?

◯ Yes (1)

◯ No (2)

◯ Partly: Please give details (5) ____

◯ Don't know (6)

Display This Question:

If Q140 = 1

Q144 When did the shortness of breath start?

◯ Immediately (within seconds of entering the water) (1)

◯ Later during the swim (3)

◯ After the swim (4)

Display This Question:

If Q140 = 1

Q146 Did you have any other symptoms at the time? Tick all that apply.

☐ Wheezing or whistling in the chest (1)

☐ Crackling sound in the chest (6)

☐ An unexplained cough (2)

☐ Coughing up phlegm, froth or fluid (3)

☐ A feeling of tightness in your chest (4)

☐ Other: Please specify (5) ____

☐ ⊗No other symptoms (7)

Display This Question:

If Q146 = 3

Q148 What colour was the phlegm, froth or fluid?

○ Yellow (1)

○ White (2)

○ Brown (3)

○ Pink, red or blood stained (4)

○ Other: Please specify (5) ____

○ Don't know (6)

Display This Question:

If Q140 = 1

Q150 Do you think the shortness of breath was due to any of the following? Tick all that apply.

- [ ] Panic attack (1)
- [ ] Smoking (2)
- [ ] Allergies such as hay fever (3)
- [ ] Cold shock response (4)
- [ ] Other reason: please specify (11) ____
- [ ] ⊗None of the above (13)

Display This Question:

If Q150 = 1

Q152 You selected panic attack. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

- ○ Yes (6)
- ○ No (13)

Display This Question:

If Q152 = 6

Q154 Did they think the shortness of breath was due to a panic attack?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Q150 = 2

Q156 You selected smoking. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q156 = 1

Q158 Did they think the shortness of breath was due to smoking?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q150 = 3

Q160 You selected allergies such as hay fever. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q160 = 1

Q162 Did they think the shortness of breath was due to allergies such as hay fever?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q150 = 4

Q164 You selected cold shock response. Did you see any health professional (e.g. doctor, nurse, paramedic) about this?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q164 = 1

Q166 Did they think the shortness of breath was due to cold shock response?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q150 = 11

Q168 You selected other reason: ${Q150/ChoiceTextEntryValue/11}. Did you see any health professional (e.g. doctor, nurse, paramedic) about this ?

◯ Yes (1)

◯ No (2)

Display This Question:

If Q168 = 1

Q170 Did they think the shortness of breath was due to ${Q150/ChoiceTextEntryValue/11}?

◯ Yes (1)

◯ No (2)

End of Block: Case ascertainment

Start of Block: Triggers

Display This Question:

If Q140 = 1

Q182
Still thinking about the <u>last time</u> you experienced shortness of breath during or straight after swimming outdoors that was out of proportion to the effort you were putting in...

Please estimate the temperature of the water in degrees Celsius?

____

Display This Question:

If Q140 = 1

QID23 Did you wear a wetsuit?

○ Yes (1)

○ No (2)

Display This Question:

If QID23 = 1

QID121 What kind of wetsuit was it?

○ Full length (1)

○ Shorty (2)

Display This Question:

If QID23 = 1

QID122 What kind of sleeves did the wetsuit have?

- ◯ Long sleeves (1)
- ◯ Short sleeves (2)
- ◯ Sleeveless (3)

Display This Question:

If QID23 = 1

QID123 Did the wetsuit feel very tight or restrictive?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If Q140 = 1

QID124 Did you have anything to drink in **the hour** prior to swimming?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If QID124 = 1

Q196 What did you drink?

- ☐ Water (4)
- ☐ Sports drink (5)
- ☐ Tea/coffee (1)
- ☐ Other: Please specify (2) ____

Display This Question:

If QID124 = 1

Q125 In total, how much did you drink in **the hour** before swimming, based on a regular bike size (500-750 ml capacity) bottle?

- ○ Less than half a bottle (1)
- ○ Half to one bottle (2)
- ○ Greater than one bottle (3)

Display This Question:

If Q140 = 1

QID26 Did you spend time warming up in the water at the start of your swim?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Q140 = 1

QID28 Did you get very nervous or anxious at any time during the swim?

◯ Yes: Please give details (1) ____

◯ No (2)

Display This Question:

If Q140 = 1

Q200 Please rate the **maximum** level of effort you put into your swim, ranging from 0% (no effort at all) to 100% (maximum effort).

◯ 0-9% (12)

◯ 10-19% (17)

◯ 20-29% (13)

◯ 30-39% (14)

◯ 40-49% (15)

◯ 50-59% (19)

◯ 60-69% (16)

◯ 70-79% (18)

◯ 80-89% (20)

◯ 90-100% (21)

Display This Question:

If Q140 = 2

*

QID22
The next few questions are about the **last time** you went swimming outdoors in the UK.

Please estimate the temperature of the water in degrees Celsius.

____

Display This Question:

If Q140 = 2

Q191 Did you wear a wetsuit?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If Q191 = 1

Q192 What kind of wetsuit was it?

- ◯ Full length (1)
- ◯ Shorty (2)

Display This Question:

If Q191 = 1

Q193 What kind of sleeves did the wetsuit have?

- ◯ Long sleeves (1)
- ◯ Short sleeves (2)
- ◯ Sleeveless (3)

Display This Question:

If Q191 = 1

Q194 Did the wetsuit feel very tight or restrictive?

- Yes (1)
- No (2)

Display This Question:

If Q140 = 2

Q195 Did you have anything to drink in **the hour** prior to swimming?

- Yes (1)
- No (2)

Display This Question:

If Q195 = 1

QID125 What did you drink?

- Water (4)
- Sports drink (5)
- Tea/coffee (1)
- Other: Please specify (2) ____

Display This Question:

If Q195 = 1

Q197 In total, how much did you drink in **the hour** before swimming, based on a regular bike size (500-750 ml capacity) bottle?

○ Less than half a bottle (1)

○ Half to one bottle (2)

○ Greater than one bottle (3)

Display This Question:

If Q140 = 2

Q198 Did you spend time warming up in the water at the start of your swim?

○ Yes (1)

○ No (2)

Display This Question:

If Q140 = 2

Q199 Did you get very nervous or anxious at any time during the swim?

○ Yes: Please give details (1) ____

○ No (2)

Display This Question:

If Q140 = 2

QID29 Please rate the **maximum** level of effort you put into your swim, ranging from 0% (no effort at all) to 100% (maximum effort).

○ 0-9% (12)

○ 10-19% (17)

○ 20-29% (13)

○ 30-39% (14)

○ 40-49% (15)

○ 50-59% (19)

○ 60-69% (16)

○ 70-79% (18)

○ 80-89% (20)

○ 90-100% (21)

End of Block: Triggers

Start of Block: Long term risk factors

Q203 Which phrase best describes your participation in open water swimming?

○ I only go open water swimming occasionally or on holiday (4)

○ I am a regular open water swimmer and **do not** take part in triathlons (1)

○ I am a regular open water swimmer and take part in triathlons (2)

QID72 In which months of the year have you participated in outdoor swimming in the UK? (Include training swims in your answer). Tick all that apply.

- ☐ January (1)
- ☐ February (2)
- ☐ March (3)
- ☐ April (4)
- ☐ May (5)
- ☐ June (6)
- ☐ July (7)
- ☐ August (8)
- ☐ September (9)
- ☐ October (10)
- ☐ November (11)
- ☐ December (12)

QID73 How many times have you been outdoor swimming in the UK in the last 12 months? (Include training swims in your answer).

- ○ 0 (1)
- ○ 1 to 4 (2)
- ○ 5 to 9 (3)
- ○ 10 to 19 (4)
- ○ 20 or more (5)

Q204 How far did you swim the last time you swam outdoors in the UK?

◯ <500m (1)

◯ 500 to 1000m (4)

◯ 1001 to 2000m (5)

◯ 2001 to 3000m (6)

◯ >3000m (7)

Q131 Do you think you have ever had symptoms of any of the following health conditions? Tick all that apply.

▢ Asthma (including exercise induced) (15)

▢ Allergies such as hay fever (16)

▢ Raynaud's disease (reduced blood flow to fingers and toes in response to cold) (3)

▢ Panic attack (9)

▢ ⊗ None of the above (8)

Display This Question:

If Q131 = 16

Q133 You selected allergies such as hay fever. Was this confirmed by a health professional?

◯ Yes (1)

◯ No (12)

Display This Question:

If Q131 = 3

Q135 You selected Raynaud's disease. Was this confirmed by a health professional?

- ◯ Yes (1)
- ◯ No (12)

Display This Question:

If Q131 = 9

Q137 You selected panic attack. Was this confirmed by a health professional?

- ◯ Yes (1)
- ◯ No (12)

QID76 On most days over the last 3 months, did you take any regular medication or nutritional supplements?

- ◯ Yes: Please specify which medications and/or supplements e.g aspirin, multivitamins (1) ____
- ◯ No (2)

QID77 Which one of these best describes you?

- ◯ I have never smoked (1)
- ◯ I used to smoke occasionally but do not smoke at all now (2)
- ◯ I used to smoke daily but do not smoke at all now (3)
- ◯ I smoke occasionally but not every day (4)
- ◯ I smoke daily (5)

Display This Question:

If QID77 = 2

Or QID77 = 3

QID78 How long ago did you stop smoking?

____

QID79 How often have you had an alcoholic drink of any kind during the last 6 months?

- ◯ Never (1)
- ◯ Monthly or less (2)
- ◯ Two to four times per month (3)
- ◯ Two to three times per week (4)
- ◯ Four or more times per week (5)

Display This Question:

If QID79 = 2

Or QID79 = 3

Or QID79 = 4

Or QID79 = 5

QID80 During the last 6 months, how many alcoholic drinks did you have on a typical day when you drank alcohol?

- ◯ 1 to 2 (1)
- ◯ 3 to 4 (2)
- ◯ 5 to 6 (3)
- ◯ 7 to 9 (4)
- ◯ 10 or more (5)

End of Block: Long term risk factors

Start of Block: Risk factors & other causes of SOB

Display This Question:

If Q140 = 1

QID100 Has a health professional ever diagnosed you with any of the following health conditions?

☐ Asthma (1)

☐ Chronic bronchitis (3)

☐ COPD (chronic obstructive pulmonary disease) (2)

☐ Emphysema (5)

☐ Heart condition: please specify (4) ____

☐ Pulmonary embolism (blood clot in the lung) (6)

☐ Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs) (7)

☐ High blood pressure (10)

☐ Diabetes (11)

☐ Pneumonia (13)

☐ Other: please specify (8) ____

☐ ⊗None of the above (9)

Display This Question:

If Q140 = 2

Q181 Has a health professional ever diagnosed you with any of the following health conditions?

- ☐ Asthma (1)
- ☐ Chronic bronchitis (3)
- ☐ COPD (chronic obstructive pulmonary disease) (2)
- ☐ Emphysema (5)
- ☐ Heart condition: please specify (4) ____
- ☐ Pulmonary embolism (blood clot in the lung) (6)
- ☐ Pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs) (7)
- ☐ High blood pressure (10)
- ☐ Diabetes (11)
- ☐ Pneumonia (13)
- ☐ Other: please specify (8) ____
- ☐ ⊗ None of the above (9)

Display This Question:

If QID100 = 1

QID102 Do you think the shortness of breath you experienced was due to asthma?

- ○ Yes (1)
- ○ No (2)
- ○ Partly (5)
- ○ Don't know (6)

Display This Question:

If QID100 = 1

QID103 Did a health professional think it was due to asthma?

- Yes (1)
- No (2)

Display This Question:

If QID100 = 3

QID104 Do you think the shortness of breath was due to chronic bronchitis?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If QID100 = 3

QID105 Did a health professional think it was due to chronic bronchitis?

- Yes (1)
- No (2)

Display This Question:

If QID100 = 2

QID106 Do you think the shortness of breath was due to COPD (chronic obstructive pulmonary disease)?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If QID100 = 2

QID107 Did a health professional think it was due to COPD?

- Yes (1)
- No (2)

Display This Question:

If QID100 = 5

QID108 Do you think the shortness of breath was due to emphysema?

- Yes (1)
- No (2)
- Partly (5)
- Don't know (6)

Display This Question:

If QID100 = 5

QID109 Did a health professional think it was due to emphysema?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID100 = 4

QID110 Do you think the shortness of breath was due to a heart condition?

◯ Yes (1)

◯ No (2)

◯ Partly (5)

◯ Don't know (6)

Display This Question:

If QID100 = 4

QID111 Did a health professional think it was due to a heart condition?

◯ Yes (1)

◯ No (2)

Display This Question:

If QID100 = 6

QID112 Do you think the shortness of breath was due to a pulmonary embolism (blood clot in the lung)?

- ○ Yes (1)
- ○ No (2)
- ○ Partly (5)
- ○ Don't know (6)

Display This Question:

If QID100 = 6

QID113 Did a health professional think it was due to a pulmonary embolism?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If QID100 = 7

QID114 Do you think the shortness of breath was due to pulmonary oedema or swimming induced pulmonary oedema (fluid on the lungs)?

- ○ Yes (1)
- ○ No (2)
- ○ Partly (5)
- ○ Don't know (6)

Display This Question:

If QID100 = 7

QID115 Did a health professional think it was due to pulmonary oedema or swimming induced pulmonary oedema?

- Yes (1)
- No (2)

Display This Question:

If QID100 = 8

QID116 Do you think the shortness of breath was due to ${QID100/ChoiceTextEntryValue/8}?

- Yes (1)
- No (2)
- Partly (4)
- Don't know (5)

Display This Question:

If QID100 = 8

QID117 Did a health professional think it was due to this?

- Yes (1)
- No (2)

End of Block: Risk factors & other causes of SOB

Start of Block: Outcomes

Display This Question:

If Q140 = 1

QID118 Did you finish your swim as planned after the last time you experienced this type of shortness of breath?

○ Yes (1)

○ No (2)

Display This Question:

If Q140 = 1

Q205 Please estimate how far you swam before you experienced the shortness of breath?

○ <500m (1)

○ 500 to 1000m (4)

○ 1001 to 2000m (5)

○ 2001 to 3000m (6)

○ >3000m (7)

Display This Question:

If Q140 = 1

QID31 Did you receive any medical attention following your most recent episode of shortness of breath during or straight after swimming outdoors?

○ Yes (1)

○ No (2)

Display This Question:

If QID31 = 1

QID42 How soon after the shortness of breath started did you receive medical attention?

- ◯ Immediately (1)
- ◯ Less than 2 hours (2)
- ◯ 2 - 11 hours (3)
- ◯ 12 - 24 hours (6)
- ◯ More than 24 hours (7)

Display This Question:

If QID31 = 1

QID33 What kind of medical attention did you receive? Tick all that apply.

- ▢ Observation only (1)
- ▢ Oxygen (3)
- ▢ Inhaler (4)
- ▢ Diuretics (8)
- ▢ Diagnostic tests e.g. x-ray, ultrasound scan, ECG (electrocardiogram), echocardiogram. Please specify (7) ____
- ▢ Other: Please specify (5) ____
- ▢ ⊗Don't know (6)

Display This Question:

If QID31 = 1

QID34 Where did you receive medical attention? Tick all that apply.

☐ On site (swim exit, medical tent etc.) (1)

☐ Ambulance (2)

☐ Hospital (3)

☐ Other healthcare facility e.g. clinic, GP surgery etc. Please specify (4)
____

Display This Question:

If QID34 = 3

QID35 Where in hospital did you receive medical attention? Tick all that apply.

☐ A&E (1)

☐ Admitted to a hospital ward (3)

☐ Outpatient clinic (2)

☐ Other: Please specify (5) ____

☐ ⊗Don't know (4)

Display This Question:

If QID35 = 3

QID36 How long did you stay in hospital?

○ Less than a day (no overnight stay) (1)

○ 1 night (2)

○ 2 nights (3)

○ 3 or more nights (4)

End of Block: Outcomes

Start of Block: Demographics

QID81 How old are you?

○ Under 20 (8)

○ 20 - 29 (1)

○ 30 - 39 (2)

○ 40 - 49 (3)

○ 50 - 59 (4)

○ 60 - 69 (5)

○ 70 or older (6)

QID82 What is your gender?

○ Male (1)

○ Female (2)

○ Prefer not to say (5)

○ Other: Please specify (6) ____

QID83 How tall are you without shoes? You can enter it in metres or in feet and inches.

○ Metres: (1) ____

○ Feet and inches: (2) ____

QID84 Which of these ethnic groups do you consider you belong to?

- White (1)
- Mixed (2)
- Asian or Asian British (3)
- Black or Black British (4)
- Chinese or other ethnic group (5)
- Prefer not to say (6)

QID85 How much do you weigh without clothes and shoes? You can enter it in kilograms, stone or pounds.

- Kilograms: (1) ____
- Stone and pounds: (2) ____
- Pounds: (8) ____

QID86 Which region do you currently live in?

- ○ South East (7)
- ○ South West (8)
- ○ London (4)
- ○ West Midlands (9)
- ○ East Midlands (2)
- ○ East of England (3)
- ○ Yorkshire and The Humber (10)
- ○ North East (5)
- ○ North West (6)
- ○ Wales (11)
- ○ Scotland (12)
- ○ N Ireland (13)
- ○ Outside the UK (14)

End of Block: Demographics
