THE IMPACT OF TRAINING LOAD ON INJURY AND ILLNESS IN A 12-WEEK TRAINING PERIOD FOR AN IRON-DISTANCE TRIATHLON

A DISSERTATION PREPARED BY DARRYN BERRY (BRRDAR003) IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN EXERCISE AND SPORTS PHYSIOTHERAPY FROM THE UNIVERSITY OF CAPE TOWN

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DECLARATION

I, Darryn Berry (BRRDAR003), hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed by candidate

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(Date)

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LIST OF ABBREVIATIONS

HRV	Heart Rate Variability
IOC	International Olympic Committee
ITBS	Iliotibial Band Syndrome
OD	Olympic Distance
OSTRC	Oslo Sports Trauma Research Centre
PFPS	Patellofemoral Pain Syndrome
sRPE	Sessional Rate of Perceived Exertion
TRIMP	Training Impulse
TRIPP	Translating Research into Injury Prevention Practice
UCT	University of Cape Town
URTI	Upper Respiratory Tract Infection
VO_2max	Maximal oxygen uptake

GLOSSARY OF TERMS

Acute injury	An injury that can be linked to a specific inciting event (such as a collision on a bicycle or a rolled ankle) (1).
Acute:chronic workload ratio	An evidence-based method of monitoring training load to prevent injuries in athletes (2).
Half-iron distance triathlon	A triathlon where the athletes must swim 1.9 km, cycle 90.1 km and run 21.1 km (3).
Illness	Any physical health problem that is not related to the musculoskeletal system (such as respiratory tract infections, gastrointestinal infections and influenza) (1).
Iron-distance triathlon	A triathlon where the athletes must swim 3.8 km, cycle 180.2 km and run 42.2 km (3).
New injury	An injury that is reported to an area of body that has previously never experienced an injury in the study period; or an injury whose characteristics do not match those of injuries previously reported in the study period to the same part of the body (1).
Olympic-distance triathlon	A triathlon where the athletes must swim 1.5 km, cycle 40 km and run 10 km (3).
Overuse injury	An injury resulting from the musculoskeletal system being unable to recover from the physiological stress of training and/or competition (4).
Recurring injury	An injury reported where the body site and nature of the injury were the same as those of an injury from the previous week (5).

Sprint-distance triathlon	A triathlon where the athletes must swim 750 m, cycle 20 km and run 5 km (3).
Substantial overuse injury	An overuse injury that leads to a moderate or severe reduction in training volume or sport performance, or a complete inability to compete in sport (1).
Substantial illness	An illness that leads to a moderate or severe reduction in training volume or sport performance, or a complete inability to compete in sport (1).
OSTRC severity scale	Severity of overuse injury or illness is calculated on a scale of 0-100, reflecting the impact of injury or illness on sports participation, training volume and sports performance. In terms of the OSTRC severity scale, 0-25 = minor injury/illness, 26-50 = mild injury/illness, 51-75 = moderate injury/illness and 76-100 = severe injury/illness (6).

ABSTRACT

BACKGROUND

Given that triathlon is recognised as an official sport by the International Olympic Committee (IOC), a focus on injury prevention strategies for participation in triathlon is necessary. A model for injury prevention programme development that is used currently is the Translating Research into Injury Prevention Practice (TRIPP) model. The literature on iron-distance is currently limited to the first two stages of this model, which focus on injury and illness epidemiology. Current research has predominantly investigated injuries and illness in professional or Olympic distance (OD) triathletes. Iron-distance triathlon is a popular form of triathlon, evidenced by the recent growth in participation in the sport from recreational to elite levels. However, there is limited evidence regarding injury or illness epidemiology for iron-distance triathlon. The impact of training loads on injury and illness in iron-distance triathletes is also poorly understood.

AIMS

The aim of this study was to determine the impact of training load on injury and illness in a 12-week training period for an iron-distance triathlon.

SPECIFIC OBJECTIVES

The objectives of this study were to (1) Describe the average weekly training load in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race; (2) Describe the total and weekly average prevalence of overuse injury, substantial overuse injury and illness, and the average severity of overuse injuries and illness in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race; (3) Determine the incidence and severity of acute injuries in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race; (4) Determine the average weekly training load threshold above which there is a significantly increased risk of injury or illness in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race; and (5) Determine any associations between the prevalence of overuse injury and risk factors associated with injury (including age, gender, history of previous injuries and triathlon experience) in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race.

METHODS

This study had a prospective, longitudinal, descriptive cohort design. Thirty-seven amateur triathletes who were training for the IRONMAN™ 2018 African Championships were included. All participants had entered for the event prior to the start of the data collection process. Participants were excluded if two or more weeks of training data were missing. Online questionnaires were used to collect weekly training load, injury and illness data over a 12-week training period. Internal training load was measured as sessional Rate of Perceived Exertion (sRPE), while external training load was measured as volume (hours). Acute training load and the acute:chronic workload ratio were used to relate training load to injuries and illness. Total and weekly average prevalence and severity of overuse injuries, substantial overuse injuries and illness were obtained.

RESULTS

Participants trained for 10.5 ± 2.8(7)(7)(7) hours per week on average, with a weekly average sRPE of 13.1 ± 1.7. The average weekly training load of participants was 8 170 ± 3 565 arbitrary units (AU). The total prevalence of injury and illness were 65% (n = 35) and 62% (n = 47) respectively. The average weekly prevalence of injury and illness were 19% (n = 7) and 9% (n = 4) respectively. The injury incidence was 9.1 per 1 000 training hours. Overuse injuries were more common than acute injuries, with a prevalence of 89% and an incidence of 8.1 per 1 000 hours. The severity of injuries was mostly mild, and the severity of illness mostly moderate. Most injuries occurred during training, and the predominant location of the injury was the knee. Illness symptoms that were reported most commonly included fatigue or malaise. There were no significant relationships between low, moderate or high training loads and injury or illness respectively.

CONCLUSION

This study identified a relatively high prevalence of injury and illness in amateur iron-distance triathletes. The small sample size significantly limited our interpretation of potential associations between training load and the prevalence of injury and illness. Future studies should consider the next step in the TRIPP protocol, namely by investigating the specific aetiology of the risks associated with injury and illness, including training load. The findings of this study highlight the importance of furthering our understanding of factors contributing to the development of injury and illness in iron-distance triathletes to support safe participation and improve performance.

CHAPTER 1: INTRODUCTION AND SCOPE OF THESIS

1.1 INTRODUCTION

Triathlon is an official Olympic sport recognised by the International Olympic Committee (IOC), with the first representation at the Olympic Games occurring in Sydney in 2000 (1, 8). Participation of amateur triathletes in the iron-distance triathlon population is increasing (1, 3). This participation in triathlon puts the athlete at risk of injury, illness, overtraining syndrome and athlete burnout (9). Overuse injuries are more common in iron-distance triathlon, possibly as a result of numerous factors, including poor training habits and the cumulative load of training for three different sports (1, 4, 10-13). Iron-distance triathletes may be at risk of illness due to exposure to a high training load; however, research in this area is limited (8, 14). Reductions in triathletes' performance have previously proven to result from symptoms of illness (15).

Injury surveillance studies provide epidemiological information that is important to the development of injury prevention programmes for participation in sporting events such as iron-distance triathlon, as well as for monitoring changes in injury occurrences (16, 17). This epidemiological information may assist in the future development of injury prevention programmes for athletes participating in endurance sports such as iron-distance triathlon.

A framework that is commonly used in the development of injury prevention studies and strategies is the Translating Research into Injury Prevention Practice (TRIPP) model (17). Based on this model, injury research should follow a continuous flow through six stages, with the final stage being real-world implementation in specific sports (17). The first two phases of the protocol involve establishing the extent and cause of the burden of injury or illness (17). For numerous reasons, iron-distance triathlon literature on the first two phases is limited. Research has been ongoing since the first triathlon took place some 30 years ago, but it has focused more on the Olympic-distance (OD) triathlon rather than the iron-distance triathlon (8). Furthermore, professional athletes have been the focus of many triathlon studies, limiting their relevance to amateur triathletes (8). Another major limitation is the fact that only two studies on iron-distance triathletes have used prospective methodologies with a new and more appropriate tool for injury surveillance (1, 8). Prospective studies are recommended by the IOC as a preferred methodology for injury surveillance in sports as they limit the bias created from injury recall, which is used in retrospective studies (4). Another limitation in the research is how 'injury' has been defined, as most studies define 'injury' in terms of time-loss (1, 6). Triathletes are known to continue training despite injuries, and so this definition limits the accuracy with which the burden of injury is captured (13). At present, only one prospective injury surveillance study has used a method that may be more appropriate for recording overuse injuries in triathletes. In this method, an injury was defined as any complaint that caused a reduction in the level of training or competition, allowing for the inclusion of injuries that did not result in a time-loss from training or competition (1).

Two key points described above indicate the need for research involving iron-distance triathletes. There are gaps in the current iron-distance triathlon literature, as outlined with respect to the TRIPP protocol. Only a handful of studies have sought to determine the exact burden of injury and illness on iron-distance triathletes, and the methods used in previous studies are inconsistent. What is currently known is that there is an associated high burden of injury and illness in iron-distance triathlon participation, but the aetiology of this burden has not been investigated (1, 8).

1.2 AIMS AND OBJECTIVES

1.2.1 Aims

The aim of this study was to determine the impact of training load on injury and illness in a 12-week training period for an iron-distance triathlon.

1.2.2 Objectives

This study had five specific objectives. This study aimed to:

- Describe the average weekly training load in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race;
- Describe the total and weekly average prevalence of overuse injury, substantial overuse injury and illness, and the average severity of overuse injuries and illness in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race;
- Determine the incidence and severity of acute injuries in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race;
- Determine the average weekly training load threshold above which there is a significantly increased risk of injury or illness in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race; and
- Determine any associations between the prevalence of overuse injury and risk factors associated with injury (including age, gender, history of previous injuries and triathlon experience) in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race.

1.2.3 Significance of this study

An overarching goal of the IOC is to ensure safe participation in sports such as iron-distance triathlon (16). Available research on the risks associated with participation in an iron-distance triathlon event is currently limited. Based on several studies, it is known that the burden of injury and illness may be high, but the risk factors for these are not known. As such, this study will aim to assist in describing the risks associated with training for and participating in an iron-distance event; in addition, it will try to identify possible risk factors that may influence the burden of injury and illness. The results from this study can form part of the first and second stages of the TRIPP protocol for the future development of an iron-distance triathlon injury prevention programme.

1.3 PLAN OF DEVELOPMENT

In preparation for the research phase of this dissertation, a comprehensive review of the literature on injury prevention protocols, training load in endurance sports, injury and illness in endurance sports and triathlete injury and illness will be presented (Chapter 2). This review is followed by a prospective cohort study that was designed to determine the potential associations between training load and injury and illness prevalence over a 12-week iron-distance triathlon training period (Chapter 3). A summary and conclusion section, including recommendations for future research, will complete this dissertation (Chapter 4).

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Participation in endurance events such as triathlon is becoming increasingly popular among amateur athletes (1, 3). Injuries are common occurrences in endurance sports, and triathlon is no exception (4, 18). With the rise in interest in triathlon among amateur athletes, it is necessary to identify the burden of injury and illness to ensure safe participation in the sport (16). The most commonly reported injuries among triathletes are overuse injuries as the result of participation in triathlon training and competition; however, triathletes do not always stop training when injuries occur (4, 12, 13). Illness is another risk of participation in triathlon, owing largely to the high training loads to which athletes are exposed (14). There is currently limited research on the burden that illness has on triathletes' training and performance (8). Training load has a major impact on the risk of injury and illness, and managing this part of an athlete's training may be an essential step in the cycle of sports injury prevention (19). This literature review will examine the role that injury research currently plays in the development of injury prevention strategies in sports. The review will firstly discuss the need for injury research in injury prevention, with a focus on current triathlon injury research. An appropriate method of studying overuse injury and illness in endurance athletes will also be presented. Training load in endurance sports will follow this section, where overtraining will be discussed extensively. Injuries and illness in endurance sports will then be discussed, with a focus on swimming, cycling, and running. The last section will focus on triathlon history, physiology and performance, injuries, and illness.

Information was sourced from sports medicine and science literature, including medical literature sourced through online databases such as PubMed, CINAHL, PEDro and Google Scholar. Keywords used in the search included: '*triathlon', 'iron-distance', 'IRONMAN™', 'injury', 'illness', 'endurance sports performance', 'triathlon performance', 'swimming performance', 'cycling performance', running performance', 'training load' and 'injury prevention'.*

2.2 CURRENT EPIDEMIOLOGY RESEARCH IN TRIATHLON

2.2.1 The relevance of injury research to injury prevention

Injury prevention measures form part of an essential task that is performed by both the International Olympic Committee (IOC) and all international sports federations, namely to ensure the protection of an athlete's health during participation in any sport (16). For successful injury prevention strategies to be implemented, injury surveillance needs to be conducted regularly.

A good injury surveillance system is dependent on the following factors: the definition of 'injury' used in the screening, the source of information acquired, characteristics on the injury documentation form and the availability of exposure data regarding training and competition (16). The IOC developed an injury report system to be used and trialled at the Beijing 2008 Olympic Games (16). Injuries considered in the study that was undertaken by the IOC required a diagnosis to be made by a team health professional (to ensure validity), and an expected time-loss needed to be given.

The limitations described in the IOC study can been seen in many other studies on injury surveillance. The major limitation identified was the fact that it was not a prospective surveillance study, as an estimated time-loss was given for injuries, on one hand, and no specific follow-up was undertaken, on the other hand. Furthermore, the definition of 'injury' that was used in the IOC study is applicable only to a population among which access to a medical professional for diagnosis is available, such as professional athletes; an amateur population might not have this access. Another limitation is the fact that amateur athletes may train or compete with injuries, and so no time-loss or medical attention injuries are recorded with this definition of 'injury' (4).

The first step in injury prevention is to describe the magnitude of the problem in terms of injury frequency and severity (20). Given the limitations of the IOC model of injury surveillance used in Beijing (16), it may prove useful to identify possible alternative methods, which record injury characteristics within sports more accurately. The most commonly used model for the development of sports injury prevention protocols is the four-stage model that was established by Van Mechelen and his colleagues in 1992 (19, 21). The limitation of this method is its failure to consider the injury prevention uptake in a sport through contextual (real-world) implementation. When used in specific sporting groups, moreover, the impact it has is not necessarily the same as when it is used in a scientific setup (17). In light of these limitations, a new model of injury prevention was developed, the Translating Research into Injury Prevention Practice (TRIPP) model (17). This is a six-stage model that incorporates targeted contextual implementation in the development of injury prevention protocols (17). The stages of the model are shown in Figure 1.

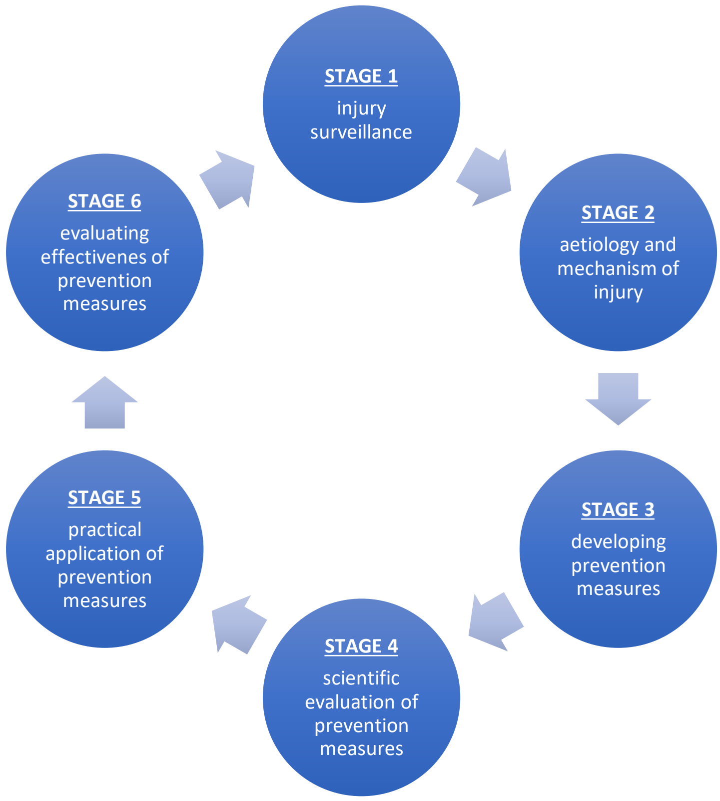

Figure 1: Sequence of sports injury prevention as outlined by the TRIPP model (17).

The contextual application of an injury prevention programme incorporates the knowledge and attitudes of players, coaches and sports bodies with respect to injury in their sport (19). It was recently suggested that the context of the injury should be applied early on rather than in the end stages of the 'sequence of prevention' of sports injuries (22). Any injury prevention programme that follows these steps in their development may be more effective in ensuring safe participation in that sport, although such a relationship has not been scientifically validated (19). Triathlon-related injury research has been scrutinised using the TRIPP method, and is discussed in detail below (3).

2.2.2 An appropriate method for studying overuse injury and illness in endurance athletes

'Medical attention' injuries are defined as *'any new musculoskeletal complaint incurred due to competition and/or training that receives medical attention regardless of the consequences with respect to absence from competition or training'* (16, 23). A time-loss definition of 'injury,' described by Fuller et al (2006), is also commonly used in studies; injury is defined as *'any new musculoskeletal complaint resulting in an athlete missing at least one day of training or competition'*.

Both of these definitions differentiate between two types of injuries, with an acute injury being one in which the onset can be linked to a specific event, while overuse injuries are those that occur without a specific, identifiable event responsible for their onset (6). Overuse injuries usually occur in sports that involve repetitive training with inadequate time in which the musculoskeletal system can recover fully from the stress of training (4, 6). In overuse injuries, the use of time-loss or medical-attention definitions may be inadequate, as research shows that endurance athletes tend to continue training or competing after overuse injuries are incurred (6). This may be due to the nature of symptoms of overuse injuries which usually develop gradually and are often transient in nature (6). Overuse injuries resulting from sports participation have not received the same attention in research as acute injuries (6).

To address the limitations on the recording of overuse injuries in endurance sport described in section 2.2.1 above, Clarsen et al (2013a) aimed to develop a more appropriate injury surveillance tool for the recording of these types of injuries. They suggested that, through regular administering of a new questionnaire, the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire, over a specified time-period, the symptoms of overuse injuries could be more accurately monitored; moreover, the severity of injuries could be based on changes in athlete function or performance, rather than on time-loss.

The OSTRC Overuse Injury Questionnaire was developed and validated by the recording of injuries over a 13-week period. The questionnaire was administered to elite junior and senior athletes competing in various sports, including cross-country skiing, handball, floorball, road cycling and volleyball. Injuries were recorded using this method as well as a currently accepted standard method for injury registration (6). The results of their study supportthe use of an alternative to the current methods for recording of overuse injuries in triathlon. Compared to previously studies in injury surveillance, the number of overuse injuries recorded using this method was more than 10 times that recorded using the previously used methods; in addition, 75% rather than 11% of athletes were affected at some stage by overuse injury. The major reason for this discrepancy involves the definition of ‘injury’: the questionnaire did not limit the definition to time-loss, but included any physical complaints causing changes in function and performance. In a follow-up study assessing the reliability of the OSTRC Overuse Injury Questionnaire, this method was shown to consistently report injury epidemiological information for overuse injury in athletes across five different sporting codes (24) .

Clarsen et al (2013b) published a second study shortly after the development of the OSTRC Overuse Injury Questionnaire (23). In the second study, the development of the OSTRC Health Problems Questionnaire included modifications that were made to produce a broader scope of health problems occurring in athletes and their impact on sports participation, training volume and sports performance (23). This questionnaire was shown to be valid and sensitive in a large heterogeneous group of 142 potential Olympic and Paralympic elite athletes, who participated in a 40-week surveillance project in the run-up to the 2012 Olympic Games. This modified approach to surveillance is better suited to a general surveillance study of injuries and illness in athletes, particularly when the cohort is heterogeneous and a wide variety of complaints is expected (23).

The epidemiology of injury is not the only element that should be recorded for injury prevention strategy development. Training load management has become increasingly popular in the management and prevention of injuries, and this information needs to be captured along with the burden of injury (3, 19). Training load can then be used as a tool in the TRIPP cycle to monitor and prevent injury resulting from participation in sports events such as triathlon (25).

2.3 TRAINING LOAD IN ENDURANCE SPORTS

2.3.1 Balancing training load

The IOC has developed a consensus statement on training load among athletes, where it is defined as the total burden applied to a human biological system (26). This definition includes physical and psychological stressors resulting from both the sport itself and beyond (26).

Athletic performance can be viewed as the balance between a negative function (e.g. fatigue, injury, illness, overtraining) and a positive function (e.g. fitness) (17). An ideal training stimulus, termed the ‘sweet spot,’ is one where the maximal performance occurs through an appropriate training load while the negative consequences of training are limited (17). Physically challenging training is needed for the development of musculoskeletal qualities shown to improve performance and guard against injury (19). A paradoxical relationship was shown to exist between the training load and injury, where the injury rates in athletes accustomed to high chronic training loads have shown to be lower than athletes that train at lower chronic training loads (19). This phenomenon was described by Gabbett et al (2016) in forming a model for training load prescription using a ratio of acute:chronic workload.

Acute workload was related to the negative functions of training, such as fatigue, and chronic workload was related to the positive functions of training, such as fitness (19). This measure proves useful for defining the link between training load and injury among endurance athletes (27). Studies that investigated team sports, such as rugby league and soccer, have shown that an acute:chronic workload ratio of 0.8-1.3, or moderate-low to moderate-high, is ideal, allowing training adaption to occur while minimising the risk of injury (7, 19). Currently, there is a dearth of research on training load and its relationship to injury among endurance athletes (28).

2.3.2 Overtraining

Overload training is an essential part of the training stimulus in athletes, and is referred to in literature as 'overreaching' (29). In functional overreaching, athletes stress the musculoskeletal or cardiovascular system enough to initiate recovery and adaption to the training stimulus (4). Symptoms of constant fatigue and the inability to recover fully after training sessions are signs that the overload stimulus has become too much for the body to process. This sort of overload is referred to as 'non-functional overreaching' or 'overtraining'. The athlete may require extended periods of rest to recover from overtraining (4). Endurance athletes, particularly triathletes, have shown to be exposed to high training volumes, and so the risk of overtraining needs to be considered in their training programmes (4).

2.3.3 Physiology of overtraining

Excessively large external and internal training loads, participation in competition, trans-meridian (across time-zones) travel and a disturbed balance between psychological stress and recovery can all result in overtraining, injury or illness (9, 25). There is a large amount of knowledge known in the sports physiology literature regarding training methods and overtraining. The scope of this thesis focuses only on measuring training load and relating it to injury and illness, and so a brief overview of overtraining specifically in triathletes is presented in this section. A study was done on 30 well trained athletes, and is used to show the understanding of the key physiological process involved in overtraining (9). The release of cortisol and catecholamine from the adrenal gland, and noradrenalin from nerve terminals, assist an individual in coping with metabolic, physical and psychological stressors (9). This same response occurs during strenuous exercise (9). The increase in cortisol, a stress hormone, is believed to be responsible for a change in the immune system, increasing the window of susceptibility to illness occurring after high-volume or high-intensity training (9). Exaggerated secretion of cortisol, as seen in excessive training involving inadequate recovery, has been shown to result in negative changes in somatic health and cognitive functions (9).

These negative changes may result in a prolonged maladaptation of several biological, metabolic, neurochemical and hormonal regulation measures, presenting as overtraining (9). These changes in the internal body systems may put athletes at an increased risk of injury and illness (9). Self-reported measures of anxiety and depression have also shown strong correlations with overtraining syndrome (9). Athlete burnout may be regarded as the last point on the overtraining continuum, and is described as the psychological, emotional and at times physical withdrawal from a previously pursued and enjoyable activity (9).

Athlete burnout has been shown to correlate with exposure to stressors outside the athlete's training, such as social stressors (9). Main et al (2010) studied 30 triathletes with different levels of performance and experience over 45 weeks to assess whether exposure to stressors had any major effect on the experience of negative health outcomes. The results suggested that a combination of normal training stressors and stressors external to sports participation (psychosocial stressors) may be sufficient to cause a stress-recovery imbalance. This imbalance may potentially lead to overtraining, injuries, illness and athlete burnout. Their study found that easier training sessions were perceived negatively by the triathletes, possibly owing to a culture within the sport in which harder training is considered better (9).

2.3.4 Identifying overtraining in athletes

The main symptoms of overtraining are continuous fatigue and reduced performance even after adequate recovery time (usually three to five days, although recovery can take up to two weeks in severely overtrained athletes) (4). Other symptoms include mood disturbance, poor sleep, 'heavy legs' and increased rates of illness and injury (4, 29-31).

Symptoms of overtraining are similar to preclinical signs of illness, and may include fatigue, myalgia, arthralgia, headache and fever (25). In recreational and sub-elite athletes, a high external and internal training load, or a large change in training load (increased volume and/or intensity) has been associated with an increased risk of illness (25). In elite athletes, however, high training loads are associated with a lower risk of illness (25). The exact risk of developing illness as a result of the physical stress of a competitive race cannot be quantified yet; however, one study involving marathon runners showed that pre-race symptoms of an upper respiratory tract infection (URTI), a higher performance intensity compared to the athlete's training and a longer duration of competition were associated with increased post-race URTI symptoms (25). To avoid overtraining and to prevent the risk of injury and illness, research advises increasing the training load by no more than 10% per week (4).

The autonomic nervous system, including the sympathetic, parasympathetic and enteric systems, is involved in day-to-day heart-rate variability (HRV). This function involves the exertion of controlled modulations of the heart rate according to internal and external stimuli, such as injury or stress from training (30). An athlete who is struggling with overtraining can be identified by a decreased HRV, whereas in a well-trained state, HRV will usually be higher (30). This method has the potential to be useful in the monitoring of training status among endurance athletes, although no scientifically researched monitoring system using this method has been implemented (30).

A more common method of identifying overtraining involves the monitoring of athletes' training load through exercise logbooks (19, 29). Logging of specific training variables by athletes can be useful to measure two important factors that are used to determine training load. These are external training load, which relates to the quantification of the competition or training distances and time, or measurements such as heart rate or power (29). The other is internal training load, which refers to the internal biological, physiological and psychological responses to the external load, and can be quantified using various measures (32). Heart rate monitoring is a popular method of measuring internal training load; however, since day-to-day fluctuations in heart rate may yield an inaccurate internal training load, this method has limitations (32). A theoretical means by which to measure overtraining in athletes involves the use of the autonomic nervous system's functions, such as HRV (30). Conflicting results have been witnessed; however, a reduction in HRV has been reported in athletes suffering from overtraining syndrome (30). The hypothesis states that this changing response of the autonomic nervous system, which controls HRV, should be seen in athletes suffering from potential non-healing injuries as well (30). Measuring of blood lactate is another useful and accurate method by which to determine internal training load; however, it is impractical to measure blood lactate during each training session as it requires blood from a finger prick and a device used for measuring (32).

The training impulse (TRIMP) value describes training load as a function of the athlete's heart rate response to exercise and the training duration within a session (32). The limitations of using the TRIMP method include the need for a heart rate monitor, the need for a steady state heart rate (limiting the quantification of interval training sessions) and the inability to quantify anaerobic modes of exercise when the heart rate increases. Using a sessional Rate of Perceived Exertion (sRPE), which is measured using the modified Borg Scale (19), is a valid and reliable method of quantifying internal training load (33). The session training load is then calculated as a function of sRPE and the training duration, and is recorded as arbitrary units (AU) or exertional minutes (19).

Using the sRPE score to measure internal training load is particularly useful as it allows for accurate measuring of aerobic and non-aerobic training efforts using subjective methods (33). By monitoring and adjusting training loads using methods such as sRPE and duration, athletes may be able to prevent symptoms of overtraining and maintain sports performance (29).

2.4 INJURIES AND ILLNESS IN ENDURANCE SPORTS

This section offers a broad overview of injury and illness in endurance sports. Triathlon is an endurance sport that combines training across three different sporting codes, and places athletes at an increased risk of injury and illness (4, 12, 13). Existing literature on triathlon-related injury and illness is limited by inconsistencies in the methodologies implemented (8, 34); hence, a deeper understanding of the current available literature on endurance sports in general may help to clarify the needs and potential risks associated with injury and illness in an endurance sport such as triathlon.

2.4.1 Injuries in endurance sports

Participation in endurance activities has been associated with more overuse injuries than acute injuries owing to repetitive micro-trauma and triathlon is no exception to this trend (4, 18). On a cellular level, overuse injuries occur as a result of an accumulation of inadequate tissue healing processes around a damaged tissue site, such as degenerated and disorganised collagen fibres in tendons (tendinopathies), or poor bone remodelling around micro-damaged bones (stress fractures) (31). Intrinsic factors such as anatomic malalignment and imbalances, and extrinsic factors such as poor training habits, extreme environments and sudden excessive change in loading are associated with an increased risk of overuse injuries in endurance athletes (10, 11, 35). In a large retrospective study on elite endurance athletes (whose sports include swimming, cross-country skiing and long-distance running), the most common complaint was overuse injuries. The anatomical site of injury was determined by the biomechanical demands of each sport, and the risk of injury with inadequate recovery time increased between sessions (35).

The occurrence of overuse injuries is anatomically linked to the specific loading requirements of the sport (35). It is thus important to consider the loading and injury patterns of swimming, cycling and running when identifying potential risk factors associated with injury in triathletes (35). The risk that an athlete has of sustaining an overuse injury has always been identified using external measures, such as biomechanical assessment. Measurement of internal factors such as heart rate, HRV, sRPE and blood lactate may also help to assess the strain on an athlete and risk of injury (30, 32). The following sub-sections will review the different disciplines of triathlon individually.

2.4.1.1 Swimming

Swimming is considered to be a non-loading stressor on the lower body and is often used as a recovery training method by endurance athletes, such as runners and cyclists (36). Shoulder pain is a commonly reported injury among competitive swimmers, who typically average around 500 000 stroke revolutions per arm each year (36, 37). The most common cause of injury among these swimmers is the result of poor swim technique (36). A study of national college swimmers in the United States of America revealed a small incidence rate of injuries, with values of 1.48 per 1 000 exposure hours among males and 1.63 per 1 000 exposure hours among females (37). Most shoulder injuries in swimming are the result of rotator cuff tendinopathy, shoulder instability or a combination of both (36). In triathlon, swimming takes up less time in both training and competition than cycling and running, and results in the fewest overuse injuries (36). Between 1-12% of all triathlon-related injuries have been attributed to the swimming stages of training and competition (3).

2.4.1.2 Cycling

Despite relatively low joint forces through the lower limb in cycling compared to other sports, repetitive training loads have been shown to cause overuse injuries to the lower back and knee among recreational and elite cyclists (38). Among recreational cyclists, 24-62% of reported injuries occur in the knee (38). A study involving 101 professional cyclists showed that lower back pain was the most common complaint, with a prevalence of 58%, followed by knee injuries, with a prevalence of 36% (38). Knee injuries caused the most severe time-loss, with most knee injuries resulting in 8-28 days of time-loss from sport (38).

Lower back pain occurs more often in cyclists using the aerodynamic position than in those using the traditional straight-up position (39). In the aerodynamic position, the rider rotates forward in the saddle, the back almost parallel to the ground, and rests the forearms on the aero bars (39).
The rules of triathlon allow athletes to ride in the aerodynamic cycling position, reducing wind resistance and thus improving their performance time in the cycling stage (39). This position puts the lower back in a more flexed position, thus increasing strain on the lumbar spine (39).

A study on professional cyclists showed that lower back and knee pain occurred the least during the off-season, and most during the pre-season; the latter is most likely the result of a sudden change in training load at the beginning of the season (38). Knee pain among cyclists commonly manifests as anterior knee pain, patella tendinopathy and iliotibial band syndrome (ITBS) (39).

The causes of anterior knee pain include increased patellofemoral contact force, which may result from increased quadriceps activity, poor force distribution due to malalignment of the patella, and poor bicycle setup (39). Triathletes often use harder gear ratios and a lower cadence than traditional cyclists during the cycling leg of an event or when training, thus increasing quadriceps activity and increasing the risk of anterior knee pain (39).

2.4.1.3 Running

There has been extensive research on running injuries. The incidence of running injuries is recorded as being between 7-59 per 1 000 hours of running exposure (40). This large variation may be the result of a difference in runners' characteristics, and of the definitions of 'injury' used in the reporting of running injuries (40). The literature on running includes a pooled reporting of 65% prevalence of injury among marathon runners, a figure that is higher than other runners who race and train for shorter distances (41). Previous injury and high training volume or load are shown to correlate with the risk of overuse injury in runners (11, 12).

A review of the literature shows that runners' injuries occur mostly at the knee and lower leg or foot (41). These incidence rates refer specifically to medial tibial stress syndrome (14-20%), Achilles tendinopathy (9-11%), plantar fasciitis (5-10%) and patellar tendinopathy (6-23%) (12, 40, 41). 'Runner's knee' is a term commonly used to describe knee pain in runners, although the term has been used in conflicting ways: some use it to describe ITBS and others to describe patellofemoral pain syndrome (PFPS) (40). Evidence suggests that ITBS develops from distal compression of the iliotibial band (ITB) over the lateral femoral condyle at 30° knee flexion (42). Patellofemoral joint pain syndrome presents as diffuse anterior knee pain around the patellofemoral joint area (43). The pathology of PFPS is likely the result of pathological changes in the lateral or medial patellofemoral joint compartment, although the extent of pathology does not necessarily correlate with pain and dysfunction experienced by runners with this condition (43). Anterior knee pain is the greatest cause of knee injuries among long-distance runners, particularly ultra-endurance runners; whether this is due mostly to ITBS, PFPS or patellar tendinopathy is unclear (12, 40).

Stress fractures of the tibia are also a common and debilitating overuse injury occurring in runners, with an incidence of 9% reported in one review of the literature (12, 40). Hip injuries including stress fractures, trochanteric bursitis and snapping hip syndrome occur infrequently in runners (12). In the hip, there is a repetitive accumulation of weight that can reach eight times one's body weight, passing through the joint with each running stride.

A weekly mileage of more than 64 km has proven to be a significant contributor to hip injury (12). In the foot, runners often sustain stress fractures, or plantar fasciitis, a degenerative process to the planter fascia causing pain at the medial calcaneal tubercle on the heel of the foot (12).

2.4.2 Illness in endurance sports

Illness is defined by the IOC as *'a health problem involving body systems other than the musculoskeletal system, such as (but not limited to) the respiratory, digestive and neurological systems, as well as non-specific or generalised, psychological and social problems'* (23). Subclinical immunological changes of illness, such as internal immune system changes, often occur prior to the development of the clinical symptoms of illness in athletes, and an alternative definition of illness that includes these symptoms may be necessary (25). One such marker is secretory immunoglobulin-A (usually measured in saliva), the quantity of which decreases during and one week prior to upper respiratory tract infections (URTI) (44). Routine testing of subclinical markers is rarely used in illness epidemiological research related to athletes (25).

Moderate physical exercise is believed to have a positive effect on natural immunity and life expectancy (25). The T-cell is the body's natural antigen that fights against illness causing pathogens, and it is possible that the increased availability of these cells may result in increased overall immunity in elite endurance athletes, but not in recreational endurance athletes (14). Periods of heavy exercise, however, appear to have an immunosuppressive effect on general immunity, increasing the risk of URTI in particular (14, 25, 45).

The physical stress of high-intensity and prolonged training or competition load in endurance athletes has been shown to cause a transient immunosuppressive effect for up to two hours after exercise (45). This effect is associated with an increased risk of subclinical (asymptomatic) immunological changes, which may increase the risk of acute illness (25). In a prospective cohort study of professional athletes competing in the International Association of Athletics Federations (IAAF) Athletics Championship, it was shown that the risk of illness among endurance athletes during the championship season was ten times that of power and speed athletes (46). Given the effect that endurance training has on the immune system, it is important to note that a compromised immune system and illness may negatively impact on an athlete's performance, although this correlation has not been determined conclusively (45). Negative symptoms of sympathetic nervous system suppression and psychological exhaustion have been recorded in triathletes after an iron-distance race (45).

These negative symptoms are measured by a reduction in pituitary-adrenal and sympathetic hormones (β-endorphin, adrenocorticotropic hormone and norepinephrine) (45). Acute illness can cause a reduction in exercise performance for between two and four days after illness, interrupted training or the missing of an event, as well as more serious medical complications, including sudden death during strenuous exercise (25). A reduction in exercise performance due to acute illness has also been linked to other factors associated with illness (25). These factors include fever, muscle wasting, impaired motor coordination, reduced muscle strength, reduced maximal oxygen uptake (VO_2max) and endurance capacity, and alterations in muscle enzyme activity and metabolic function (25).

Illness in endurance athletes may present as more severe medical conditions that may be life-threatening, such as exercise-induced hyponatremia or severe heat illness (31). Symptoms of heat illness in endurance athletes include nausea, vomiting, dizziness, an irregular heart rate, heart palpitations and syncope (temporary loss of consciousness) (46). Healthcare providers at endurance events treat these conditions with extreme care due to the risk of more severe complications developing if they are not treated properly (46).

2.5 TRIATHLON

2.5.1 History of triathlon

Triathlon is a relatively modern multi-sport event that includes swimming, cycling and running (taking place in that order), and in which athletes of all levels, from amateur to professional, are able to participate (34). The first-ever triathlon took place in San Diego, California, in 1974, and was called the Mission Bay Triathlon (8). The IOC recognised triathlon as an official sport in 1994 owing to its contribution to a movement for increased fitness and health consciousness. Triathlon was represented at the Olympic Games for the first time in Sydney in 2000 (8). Currently, there are 122 nations that are affiliated with the International Triathlon Union (47).

There are four official distance categories in triathlon, including the sprint distance (700 m swim, 20 km cycle, 5 km run), Olympic distance (OD) (1.5 km swim, 40 km cycle, 10 km run), medium- or half-iron distance (1.9 km swim, 90 km cycle, 21.1 km run), and long or iron-distance (3.8 km swim, 180 km cycle, 42.2 km run) (8). The longest-distance triathlon, the iron-distance (commonly known as the IRONMAN™ event), was held for the first time in Hawaii in 1978, and included only 15 participants (34). Previously, only professional athletes participated in the iron-distance event with amateurs participating mostly in the OD event.

More recently, there has been an increase in the number of amateur participants in both the OD and iron-distance events (8, 34). Iron-distance triathlons are classified as ultra-endurance events, as they last longer than six hours (29). Researchers have started to investigate triathlon more regularly owing to the unique nature of physical development among athletes who are training for three separate disciplines (18).

2.5.2 Physiology and performance in triathlon

A great deal of research has been undertaken regarding the most effective methods for an athlete to improve their performance in iron-distance triathlons. Currently, a low body-fat percentage, low sum of skin-fold thickness, high weekly cycling volume, faster personal-best time in an OD event and a faster best-marathon time are shown to be the main predictors of best performance in male iron-distance triathletes (48). In females, success at an event may be predicted by a faster run training speed (49, 50). Iron-distance triathletes may benefit from a higher total weekly training distance rather than a higher training speed when preparing for an event (48). Other proven methods for performance improvement among triathletes include the use of drafting in the swim and cycling legs, although current regulations forbid drafting during the cycling leg of iron-distance events (51).

In a single study, male iron-distance athletes were shown to be anthropometrically very similar to runners; in addition, a low body-fat percentage was a predictor of a faster race time (52). In contrast, female participants showed no benefit as a result of lower or higher body-fat percentages, but rather benefitted from a higher total training volume (52). There are many factors that determine success in an ultra-distance endurance event; however, an athlete's ability to maintain a higher absolute speed for a longer time period compared to other competitors is paramount (29).

In a small study of nine amateur triathletes, a lower performance time at the iron-distance event was associated with higher training hours performed at lower intensities over fewer training hours at higher intensities (53). This type of training method is in line with the 80:20 method described by Laursen et al (2011), who argue that best performance in iron-distance triathlon can be achieved when 80% of training is below lactate accumulation threshold values, while 20% is above threshold values (34).

Maximal oxygen uptake (VO_2max) is a measure of an athlete's ability to transfer aerobic energy. Elite triathletes usually have a higher VO_2max owing to their high-functioning cardiovascular systems, which have been linked to better race times (54).

Another physiological measure of endurance ability in endurance athletes is the arterio-venous oxygen ratio, reflecting the peripheral metabolic system's ability to utilise the large quantity of circulating oxygen (54). In endurance athletes, training adaptation causes increased capillary density in muscles, enlarged mitochondria (the number of which is increased) and increased enzymatic activity in the transfer of energy within the muscles (54).

The interaction of VO_2max, lactate (or ventilatory) threshold and economy of motion is essential for yielding top performances among both male and female endurance athletes (55). Lactate threshold is a value that describes the intensity of exercise (percentage of VO_2max) where 4 mmol/L of lactate has accumulated in the working tissue (54). To improve performance in iron-distance triathlon, athletes need to try to train the body's energy systems to use a higher percentage of VO_2max while remaining below the lactate threshold (54). It has previously been shown that, during an iron-distance race, the lactate thresholds will differ between each discipline (54). This variation is most likely the result of the distinct energy demands and musculature usage of each discipline, and athletes should look to train each energy system individually (54). In iron-distance athletes, the performance of males is generally 10-14% better than that of females, possibly owing to the ability to achieve higher VO_2max during exercise, among other factors (55). Higher VO_2max has been linked to lower body fat, increased oxygen-carrying capacity and increased muscle mass (55).

Among amateur athletes, it is also shown that cycling below the lactate threshold allows for an improved run performance and overall improved race time (51). This effect is linked to the reduced usage of carbohydrates that have been stored for use later in the race (51). To improve performance in the run, iron-distance triathletes can adopt a lower cadence in the last part of the cycle leg of a triathlon, as this method increases the expense of leg musculature energy metabolism and reduces the volume of oxygen consumed during the run (51).

A common area of interest in the sports performance network is the effort to identify the upper limit limitation to improved performance. There are many beliefs regarding this topic, which include the role of the respiratory and cardiovascular systems, the cellular function of different body organs, the Central Governor theory and more recently the Integrative Governor theory (56). The Central Governor theory focuses on the role of the brain in the limiting of exercise performance, while the Integrative Governor theory identifies the potential interaction of psychological and peripheral drives during exercise that prevents catastrophic injury and maintains homeostasis (56).

Iron-distance triathlon is an ultra-endurance event that can last up to 17 hours, and so research may need to identify the role that this theory plays in the performance of iron-distance triathletes.

2.5.3 Injury epidemiology in triathlon

2.5.3.1 A review of triathlon literature using the TRIPP model

Based on a review of existing literature, it is evident that there are some methodological inconsistencies in research regarding triathlon (3). The methods used to record overuse injuries in triathletes has been scrutinised owing to the challenge of accurately defining overuse injury in research, among other limitations. It is thus a challenge to quantify the exact magnitude of the risk of injury and illness from participation in triathlon (1, 6). The goal of the TRIPP method for injury prevention research, described earlier in this review, is to provide injury prevention methods that are evidence-based and contextually relevant to a specified group (3).

The first stage of the TRIPP model involves reporting the extent of the injury problem. This stage is currently the main focus of triathlon-related research (3). The methods for reporting and recording of injuries has previously been inconsistent (3). For example, when injuries (acute or overuse) were reported as a percentage of total injuries, training injuries were the most common. However, if expressed as a percentage of exposure hours, competition injuries were the most common (3). Other limitations that were identified include the varying duration of data reporting periods, and the use of retrospective data collection methods (3).

To compare the different methodologies used in injury surveillance, a study was performed on injuries in triathletes using 12-month retrospective and 12-month prospective methodologies (8). A summary of key findings from this study can be seen in Table 1.

Table 1: Overview of key findings from a study that compared injury epidemiology in triathletes using retrospective and prospective methodologies (8).

	Retrospective analysis	Prospective analysis
Competition incidence of injury (per 1 000 hours)	9.2	18.5
Training incidence of injury (per 1 000 hours)	0.7	1.4
Average incidence of injury (per 1 000 hours)	0.9	1.9
Acute injuries (%)	71	30
Overuse injuries (%)	29	70

The findings of this study, which was performed by Zwingenberger et al. (2014), showed that a recall period of 12 months can influence the trend of the results. Retrospective data collection showed more acute injuries and fewer overuse injuries, while prospective data collection showed a higher incidence of overuse injury and fewer acute injuries (8). The retrospective population size of 212 is a strength of this study. The prospective analysis, meanwhile, involved a population size of 49. The small size of the sample used in the prospective analysis may cause the burden of injury to be underestimated due to injuries being observed in a very limited group of participants. Making inferences form a small cohort onto a larger group of athletes is than not as reliable; hence, the results should be read as a trend and not as indicators of definite differences (8). To fully understand the burden of injury in the triathlon population, the literature should be interpreted with caution, as the comparison of studies is currently limited due to the difference in definitions of 'injury', as well as the inconsistency in data collection methods (3).

The second stage of the TRIPP model involves understanding the aetiology and mechanisms of injury. At present, the literature related to triathlon shows that non-traumatic injuries resulting from running (followed by cycling) are most common (3). The use of a retrospective methods in most research papers is a limitation on the interpretation of risk factors associated with injury in triathlon, as the recall of injury details is shown to be inaccurate in comparison with prospective methods (3). Prospective research is therefore required to identify the mechanisms and possible risk factors associated with injury in triathlon (23).

Stages three to six of the TRIPP model involve the development, implementation and evaluation of injury prevention measures. Injury prevention measures in triathlon have been studied in single events, with a focus on secondary and tertiary prevention strategies. Primary injury prevention measures need to be prioritised in triathlons, since only stretching, warming up and cooling down have been formally investigated, while no significant relationship to risk of injury was shown (3). The primary injury prevention methods used currently in triathlon have been developed by organisations and sports governing bodies for swimming, cycling and running individually, rather than from specific scientific research undertaken by triathlon organisations (3). Before implementing injury prevention strategies, triathlon research should focus on stages one to two of the TRIPP model to establish the burden of injury and illness from participation in the sport.

The limitations of research into illness occurring in athletes have been mentioned. These limitations include the need for self-reporting of symptoms by study participants (symptoms that may not reflect the clinical signs of illness accurately), as well as the high price of clinical assessment when undertaken by a physician to diagnose illness (25). The use of clinical symptoms or self-reported symptoms of illness to record illness in athletes is a limitation, as symptoms can be caused by allergies or inflammation resulting from causes such as the inhalation of cold, dry or polluted air; these symptoms may even be a sign of overtraining (25). A better method for predicting illness in triathlon may be the testing of immune system markers that predict the onset of acute illness, although the sensitivity, specificity and cost-effectiveness of this method has not been determined (25).

The methods used to record overuse injuries in triathletes has been scrutinised owing to the difficulty encountered in accurately defining overuse injury in research, among other limitations. It is thus challenging to quantify the precise magnitude of the risk of injury or illness from participation in triathlon (1, 6). Based on the current literature, future research should aim to use alternative methods for surveillance that will improve the recording of the burden of injury or illness from participation in triathlon. An alternative method has been developed and used in previous iron-distance triathlon research. This method is discussed in detail below (1, 6).

2.5.3.2 Current knowledge from triathlon research

The research on injuries in triathlon has accumulated since the sport was conceived. Much of the research considers OD and iron-distance triathletes. While most of the research is in agreement regarding injury epidemiology, there are some conflicting results. An overview of selected triathlon-specific injury studies is shown in Table 2. It is shown that the most common type of injuries occurring in triathlon are overuse injuries that result from the cumulative stress placed on the musculoskeletal system during training (4).

Of the three disciplines, running has been shown to be the cause of most overuse injuries in triathletes (1, 3, 8, 12, 13, 36, 57, 58). A study of elite triathletes found that overuse injuries correspond to the amount of time spent on speed training (27). The study included 35 elite OD and iron-distance triathletes, and so it cannot be assumed that speed training may lead to overuse injuries in amateur athletes (27). In an earlier study, cyclists were found to exhibit the highest incidence of injury (58). In the definition of 'injury' that was used, however, an athlete is said to be injured only if he/she stops training or competing. This definition, known as a time-loss definition, excludes situations where athletes continue to train despite the injury (13).

Another possible reason for the recorded higher incidence in cyclists is the fact that most time-loss injuries in triathlon training or competition have been shown to result from the cycling discipline (1, 3).

Table 2: Overview of selected triathlon-specific injury studies, identifying the event distance, study design, population size and athletic status of the population under investigation.

Author	Event distance	Study design	Population size	Athlete status
O'Toole et al (1989)	Iron distance	Retrospective (12 months)	n = 95	Elite and amateur
Korkia et al (1994)	Sprint, Olympic, half-iron and iron distance	Prospective (8 weeks)	n = 155	Elite and amateur
Wilk et al (1995)	Not specified	Retrospective (triathlon career)	n = 72	Amateur
Vleck and Garbutt (1997)	Olympic distance	Retrospective (5 years)	n = 194	Elite and amateur
Cipriani et al (1998)	Not specified	Retrospective (10 years)	n = 52	Amateur
Clements et al (1999)	Not specified	Retrospective (3 years)	n = 58	Elite and amateur
Burns et al (2003)	Not specified	Retrospective (6 months pre-season, 10 weeks competition)	n = 131	Elite and amateur
Egermann et al (2003)	Iron distance	Retrospective (triathlon career)	n = 656	Elite and amateur
Shaw et al. (2004)	Not specified	Retrospective (12 months)	n = 258	Elite and amateur
Villavicencio et al. (2006)	Sprint, Olympic, half-iron and iron distance	Retrospective (triathlon career)	n = 164	Elite and amateur
Vleck et al (2010)	Olympic and iron distance	Retrospective (5 years)	n = 31	Elite
Migliorini (2011)	Sprint, Olympic, half-iron and iron distance	Retrospective (3 years)	n = 24	Elite
Andersen et al (2013)	Iron distance	Prospective (26 weeks)	n = 174	Elite and amateur
Zwingenberger et al (2014)	Sprint, Olympic, half-iron and iron distance	Retrospective (1 year) Prospective (1 year)	n = 212 (retrospective) n = 49 (prospective)	Amateur

Owing to the high level of stress placed on a triathlete's body during training or competition, there is a high probability that he/she will sustain some form of an injury (1, 27). In a prospective injury surveillance study involving iron-distance triathletes, up to 87% of the cohort sustained at least one overuse injury (1). This study also showed that more than 50% of the cohort was carrying an injury at any point in time; of these athletes, 20% had overuse injuries requiring them to miss training days (1). These figures highlight the high prevalence of overuse injury among iron-distance triathletes (1). The most common site of overuse injury in triathletes is the lower limb (specifically knee and ankle/foot), lower back and shoulder (1, 3, 13, 57, 58).

Injuries in triathlon, whether acute or an aggravation of underlying overuse injuries, are more common when one is participating in a competition (8). These injuries may be the result of multiple factors, including increased pressure to perform and finish the race, or higher-intensity efforts during the race (8). One possible cause is an increased response of the sympathetic nervous system during the competition, causing athletes to ignore their pain and thus aggravate any underlying injuries, as well as exposing them to more risk of injury during these periods (8). In another study, Burns et al (2003) compared the pre-season training period to the competition training period and showed that, during the competition period, there was a higher incidence of injury (57). This increase may be the result of taking part in shorter, more intense competition events as opposed to longer, slower training sessions (57). In another study, training was shown to result in a higher incidence of injury than competition, although the study used a time-loss definition of injury (58).

Acute injuries in triathlon do not occur as often as overuse injuries (1, 8, 13, 57). Acute injuries occur most often in the cycling discipline as a result of falls or accidents; they usually include abrasions, contusions, blisters, muscle strains and fractures (1, 18, 57, 58). In one prospective study, the severity of acute injury in iron-distance athletes was shown to be mostly moderate (i.e. a time-loss of 8-28 days) (1). The moderate loss of training days may be the consequence of triathletes' ability to train across three different sports, preventing them from missing many training days despite injuries (13). The higher incidence of overuse injuries as opposed to acute injuries is indicative of the cumulative stress placed on the triathlete's body during training, and shows that training load management is essential when it comes to preventing injuries and maintaining performance (13).

Injury prevention strategies, such as training load management, are increasingly common among athletes at all levels and in all sports (16). For triathletes, a common method of injury prevention involves the manipulation of training sessions across three different sports, or else increasing the intensity of one discipline while taking a break from the aggravating discipline (4, 13). In this way, triathletes are able to continue training even though they are injured, or can balance their training volume to prevent injury (4, 13).

2.5.4 Risk factors associated with injury in triathlon

Research into risk factors for injury in triathlon are limited in quantity. This literature review presents a brief overview of external risk factors for injury in triathlon. These include training volume, training habits, triathlon event distance, years experience in triathlon, and level of athlete. One internal risk factor injury, namely having a history of injury, is also briefly discussed. The risk factors for injury and illness that were investigated in the current study were internal and external training load variables. These are presented later in this thesis.

2.5.4.1 Training load

Endurance athletes with a training volume greater than 10 hours per week are shown to have a higher risk of injury (8). Average training volume in iron-distance triathletes has been reported to range from 11.1-15.6 hours per week for amateur athletes, while professional athletes can accumulate up to 30 hours per week (1, 8, 13, 34). In a study of recreational triathletes, athletes who trained less than eight hours or more than 15 hours per week experienced a significantly increased risk of injury (59). Training load in triathletes is reported to be similar if not slightly more than in athletes who are focusing on individual endurance sports (4). Paradoxically, injury rates appear to be lower in triathletes than in individual discipline athletes, possibly owing to the use of cross-training methods and training volume management across three sports in triathlon (4, 8, 18).

Cycling requires the highest number of training hours from iron-distance athletes, followed by running and then swimming. These hours may be manipulated during periods of injury if necessary (1, 4, 8, 36). In a comparison of recreational iron-distance triathletes and ultra-endurance cyclists, iron-distance athletes were shown to accumulate longer total training times, but less distance and cycling training time, per week (48). In running training, triathletes are shown to accumulate the same weekly mileage as marathon runners (30).

2.5.4.2 Discipline-specific risk factors

The running leg of a triathlon is considered to determine whether a race is good or bad (12). It is also reported to be the most difficult part of the race owing to the accumulation of fatigue in the legs as a result of swimming and cycling (12). After the cycle, the body needs to adjust to regain the neuromuscular and elastic efficiency that is necessary for force dissipation in running (18). There is also a change from concentric muscle activity during cycling to eccentric activity in running, as well as from an unloaded state in cycling to a loaded state in running (18). The transition from cycling to running in a triathlon is therefore an area of high risk in terms of overuse injury (in the knee and lower back particularly), compared to the other legs of a triathlon (12, 18).

Athletes who compete in longer-distance triathlon, such as iron-distance events, accumulate more stress on the body during training and during competition, and are thus more susceptible to overuse injuries (18, 47). Risk factors that are associated with the development of overuse injury in triathletes include a history of injury, higher number of years of participation in the sport and a higher level of performance (8, 13, 57, 58). A history of injury can increase the risk of injury if a previous injury has not healed properly (11). This can be due to the healed tissue not functioning as highly as the uninjured tissue, or the cause of the initial injury may not have been corrected (11). A higher number of years of participation in triathlon may increase the cumulative stress on the musculoskeletal system, thereby increasing risk of injury (57). Athletes performing at a higher level, such as elite athletes, are at an increased risk of injury because they usually train and compete at higher speeds and intensities (57, 58).

Triathletes that begin their sporting careers as swimmers may be at increased risk of ITBS owing to a reduction in hip abduction moment, causing altered biomechanics at mid-stance during the run and ultimately an impingement of the iliotibial band against the lateral femoral condyle of the femur (18). Having a long history of running, as well as a higher weekly load of running, also contributes to the development of overuse injury owing to the high repetitive stress placed on the body during running (13, 57).

2.5.5 Illness epidemiology in triathlon

The available research on illness in triathlon participation is limited; however, it has been reported that triathletes experience reductions in performance that are associated with symptoms of illness (15).

One study reported an illness incidence of 5.3 per 1 000 athlete days over a 24-week surveillance period (1). Of these illnesses, the majority of the time-loss that was caused ranged from one to seven days (1).

Periods of heavy exercise are shown to place athletes at risk of URTI via an immunosuppressive mechanism of the body's natural immune system (14). Iron-distance triathletes' training loads put them at an increased risk of developing new infections in periods of high training volume and in recovery periods (14). A study that investigated a group of eight elite triathletes over one season reported 247 incidences of illness symptoms; these symptoms often coincided with a self-reported drop in performance of up to 15% (15). These changes in performance might be the result of overtraining as opposed to illness, as the symptoms are similar in both cases. This similarity highlights a potential limitation of research that involves self-reporting of illness (15). Another factor that puts triathletes at risk of developing infections is the possibility of swimming in contaminated water (15). In a study involving medical reports from a single iron-distance event, it was shown that exercise-associated collapse, dehydration and exhaustion occurred more commonly than any other medical problems or illness (60).

2.6 SUMMARY OF THE LITERATURE

Triathlons, and particularly iron-distance triathlons, are growing in popularity; however, there is currently very little prospective research on the burden of injury and illness in triathletes at all levels (8). Most studies use retrospective methodologies and definitions that may not accurately record the epidemiology of injury and illness in endurance athletes (8, 34). The IOC and triathlon sports federations have a responsibility to ensure the safe participation in sports events such as iron-distance triathlon, and injury prevention forms a big part of this responsibility (16). Endurance athletes, and particularly ultra-endurance athletes such as iron-distance triathletes, are at risk of overuse injury and illness (4, 18) owing to the high volume of training load during training periods and competition (4, 18). Triathletes are known to continue training despite injury; hence, the burden of injury may not be accurately quantified using currently popular definitions of injury involving time-loss (6). To ensure the successful implementation of injury prevention strategies, the epidemiology of injury and illness in iron-distance triathlon needs to be established; this process is the first step in the 'sequence of injury prevention' (19). Epidemiology data needs to be established using a method that more accurately reflects the burden that injury and illness may have on iron-distance triathletes (1, 6). The following chapter describes an epidemiological study that investigated training load, injury and illness characteristics among iron-distance triathletes over a 12-week training period.

CHAPTER 3: THE IMPACT OF TRAINING LOAD ON INJURY AND ILLNESS IN A 12-WEEK TRAINING PERIOD FOR AN IRON DISTANCE TRIATHLON

3.1 INTRODUCTION

Iron-distance triathlons are increasingly popular among amateur athletes (1, 8). Exposure to the stress related to triathlon training has been associated with the experience of injury, illness, overtraining and athlete burnout (9). Triathletes are particularly prone to overuse injuries owing to the cumulative load of training in three sporting disciplines, as well as the limited recovery period between sessions (4, 12, 13). Triathletes are usually able to continue training with these injuries, however, by training across the three sport disciplines. (4). Research on illness related to triathlon participation is limited; however, it is known that high training loads put triathletes at an increased risk of developing new infections (14).

The main limitation on the existing triathlon research is the use of non-standardised definitions of ‘injury’ and ‘illness’ (1, 3, 17). Only one prospective injury surveillance study uses a method that may be more appropriate for the recording of overuse injuries in triathletes (1). In this method, the definition and severity of injuries are based on a reduction in the level of training or competition, rather than time lost from training; they are also different from the ‘medical attention’ definition (1). Based on this limitation, this study aimed to determine the impact of training load on injury and illness in a 12-week preparation period for iron-distance triathlon, and employed a similar method proposed by Andersen et al (2013). The specific objectives have been described in Section 1.2.2 (page 2).

3.2 METHODS

3.2.1 Study design

This study had a prospective, longitudinal, descriptive cohort design. This study followed participants over a 12-week training period leading up to, and including, the IRONMAN™ 2018 African Championship event. Weekly training load, injury and illness in participants were monitored.

3.2.2 Participants

3.2.2.1 Recruitment

Ethical clearance was obtained from the Human Research Ethics Committee (HREC) of the Faculty of Health Sciences (FHS), University of Cape Town (UCT) prior to the recruitment of triathletes (Appendix I).

Recruitment was undertaken by means of an advertisement sent via the IRONMAN™ 2018 African Championship race organisers, social media for the event, six provincial triathlon associations and three triathlon clubs. A request form (Appendix II) containing information about the study was sent to the relevant associations for assistance in the distribution of an informative study advertisement (Appendix III), which was sent to all triathletes entered for the event. Advertising via social media and word-of-mouth was undertaken using the same study advertisement. Interested triathletes then contacted the researcher via email. Triathletes who expressed interest in participating were subsequently sent an informed consent form, which required their signature, as well as a demographic information form, which they were requested to complete. Once the signed informed consent form and completed demographic form were received by the researcher, the triathletes were successfully recruited as participants in the study.

3.2.2.2 Inclusion criteria

All triathletes who agreed to participate in the study, and who were entered for the IRONMAN™ 2018 African Championship event at the beginning of the data collection period, were included in the study. Both professional and amateur triathletes were included. Participants with an overuse or acute injury at the start of the study were included in the study; these participants were included because this study reported prevalence. Participants with an injury at the beginning of the study period have been shown to be at risk of an overuse injury; therefore, it was essential to include them in the study (6). Data from participants that were unable to continue training or compete in the race due to injury or illness were included. These data were included because the study reported average weekly prevalence, and data obtained up until the point at which injury or illness prevented them from continuing could still be used in the analysis. Participants with access to a computer and internet, and who had basic computer literacy, were included in this study. Participants needed to understand English and exhibit reasonable literacy rates; if participants struggled to understand any part of the questionnaire, however, the researcher was available to assist via email or telephone.

3.2.2.3 Exclusion criteria

Participants who did not submit data for more than two consecutive weeks were excluded. Participants that were struggling with an injury/illness were still required to fill in the weekly questionnaire, so this did not affect whether they were excluded or not. Any data collected up to the point of exclusion was still included in the study as a weekly average prevalence and severity of injury and illness was reported.

They were excluded because the average prevalence has shown to not significantly be affected by data that is collected in every second week, but is significantly affected by more than two weeks of missing data (23).

3.2.2.4 Sample size determination

A sample of convenience was used. The 2018 IRONMAN™ event had 3 000 individual entries. Data derived from a previous study on injury prevalence in iron-distance triathletes was used to ensure that the sample size would provide sufficient statistical power (1). StatCalc by EpiInfo was used to determine the sample size, based on the values in the study by Andersen et al. (2013). In this previous study, a sample size of 174 participants was used for statistical power (1). With an expected population of 3 000 IRONMAN™ participants, an expected prevalence of serious overuse injuries of 20% (1) and an acceptable margin of error (i.e. 5%), sample sizes of 102, 164, and 227 participants were required for 80%, 90% and 95% statistical power respectively.

3.2.3 Instrumentation

3.2.3.1 Informed consent form

All study participants read, and signed the informed consent form prior to taking parting in the research (Appendix IV). The form was sent to the triathlete once they had expressed interest in participating in the study. The informed consent form included an information sheet with all relevant information relating to the study, including the significance of the study, and the risk and benefit to participants.

3.2.3.2 Demographic information form

All study participants completed a self-administered form (Appendix V) that was developed by the researcher. Age, sex, number of years' experience in triathlon, number of completed IRONMAN™ triathlons, current training hours and a previous history of injury to specific anatomical regions were recorded. All participants completed the demographic information form before the commencement of the study.

3.2.3.3 The Oslo Sports Trauma Research Centre Questionnaire on Health Problems

The Oslo Sports Trauma Research Centre (OSTRC) Questionnaire on Health Problems (Appendix VI-Section A) was used to capture data on health problems, including overuse injury, acute injury and illness.

This questionnaire was developed in 2013 as a modified version of the OSTRC Overuse Injury Questionnaire, in which the modified questions included the reporting of a broader scope of injury and illness (23).

The original OSTRC Overuse Injury Questionnaire was also developed in 2013 to better define the impact of overuse injury on athletes. Severity of overuse injury is not calculated with respect to time-loss from sport, but rather on a scale of 0-100, reflecting the impact of injury on sports participation, training volume and performance (6). The OSTRC Overuse Injury Questionnaire was shown to be a valid tool in the comparison of overuse injuries occurring in athletes across five different sporting codes (24). The OSTRC Questionnaire on Health Problems proved valid and sensitive for continuous injury recording in a large, heterogeneous group of elite athletes (23).

In this study, prevalence and severity of overuse injuries or illness were obtained by capturing data using this tool. Data was reported as a total and weekly average prevalence. An average prevalence was used as opposed to a total prevalence alone to enable the inclusion of injuries (acute and overuse) and illness that were present at the beginning of the study (6). When recording the prevalence at the end of the study period, data from the first questionnaire was removed from the dataset, as an artificially high prevalence has been shown in this dataset (6). Substantial overuse injuries and illness were also recorded.

3.2.3.4 Training/competition volume question

Internal training load was obtained using a weekly average sessional Rate of Perceived Exhaustion (sRPE) value, measured on the modified Borg Scale (Appendix VI- Section B). This sRPE value has proven useful in the recording of perceptions of physical exertion that is experienced in a wide range of exercise modes (61). An average weekly sRPE value for each discipline has been used in previous iron-distance research (1). The total training load can be described as a function of training volume, multiplied by the sRPE, and expressed as AU or exertional minutes (19). An additional question was added to the OSTRC Questionnaire on Health Problems for the purpose of registering the total training volume (hours) and average weekly sRPE in each discipline, as well as time in competition (Appendix VI- Section B). This additional question was used in another study on surveillance of injury and illness in iron-distance athletes (1). Total training volume and average weekly sRPE for other forms of training (core, strength, balance and other) were also recorded in accordance with previous methods (1). To provide accurate information, participants were encouraged to keep daily records of their training and sRPE.

The acute:chronic workload ratio is obtained by calculating the ratio of acute training load over the period of one week to chronic or rolling training load (over three to six weeks) (19). A value of 0.8-1.3 indicates a 'sweet spot' for training, corresponding to a lower risk of injury (19).

A value of less than 0.8 or more than 1.5 has been shown to involve increased risk of injury (19). This ratio was used in this study to relate injuries to training load. A three-week rolling training load was used for the chronic component, and the weekly training load was used for the acute component.

3.2.3.5 Acute injury question

An additional question was included in the OSTRC Questionnaire on Health Problems (Appendix VI – Section C) to register acute injuries. This question was used in another study on surveillance of injury and illness in iron-distance athletes (1). Any complaints recorded in the weekly questionnaire were again recorded, regardless of whether they were recorded in the previous questions. This questionnaire classified acute injuries as those that can be linked to a specific inciting event (such as a collision on a bicycle or a rolled ankle), where the onset was sudden in nature. To separate acute injuries from overuse injuries using this definition, more details of the injury were obtained using this questionnaire. Incidence data for acute and overuse injuries was presented as number of injuries per 1 000 hours of training exposure (5).

3.2.3.6 Validation of the OSTRC Questionnaire on Health Problems for Triathlon

The OSTRC Questionnaire on Health Problems and the demographic information form were assessed by a panel of field experts for construct and content validity in a triathlon population. The form used for contacting the relevant individuals can be reviewed in Appendix VII. The panel of experts was chosen based on their history of completing injury surveillance research in sports and exercise, and experience with endurance athletes as sports physiotherapists, physicians or exercise scientists. The experts were asked to comment individually as to whether the questions were relevant and important for the recording of training load, injury and illness in a population of endurance athletes; they were also asked whether the questions were clear and understandable. Expert reviewers had the opportunity to add any question that they felt needed to appear in the questionnaire. The form and the experts' responses can be reviewed in Appendix VIII and Appendix IX, respectively. The researcher and the supervisors consolidated the feedback to produce an updated questionnaire, which was sent back to the panel of experts for approval and consensus.

3.2.3.7 Feasibility of the OSTRC Questionnaire on Health Problems

The OSTRC Questionnaire on Health Problems has never been used in a South African context; therefore, the appropriateness of this test with respect to the study was tested. The feasibility study used the online version of the questionnaire developed using SurveyMonkey™ software, as well as the demographic information form developed by the researcher.

The aim of the feasibility study was to assess the feasibility of using a training load, overuse injury and illness questionnaire in a South African context. The specific objectives of the feasibility study were the establishment of whether the questions were appropriate for use in a small cohort of South African triathletes, as well as whether the questionnaire was easy to complete. The form used for feedback on the online questionnaire can be viewed in Appendix X.

Ten percent of the expected sample size calculation (see 3.2.2.4 on page 28 above) was required for the feasibility study; hence, 30 participants were required. However, a total of 10 participants, who were currently training and/or participating in OD triathlons, were recruited for the feasibility study. The small sample size is the result of a limited time-frame, in which difficulty was experienced in the recruiting of participants for the feasibility study. Data from the feasibility study were not included in the final analysis as the athletes were not training for an iron-distance event. The participants were required to complete the online questionnaire once a week for two weeks. The results of the feasibility test showed that the questionnaire required between 5-10 minutes to complete, and that there was no misunderstanding of the structure of or use of language in the questions.

3.2.4 Data collection procedure

On each Sunday during the 12 weeks leading up to the IRONMAN™ event, an automated online survey programme (SurveyMonkey™) sent each participant an email linking them to the injury questionnaire. The questionnaire had been designed so that it could not be completed until all the questions had been answered. If no response occurred within three days, an automatic email was sent to the participant reminding him/her to complete the questionnaire. If no injuries or illnesses occurred, the questionnaire still needed completing to provide a comprehensive dataset and accurately record training load. Unnecessary questions were skipped throughout the questionnaire using a skip logic within the programme.

3.2.5 Statistical analyses

All data was captured in a spreadsheet using Microsoft® Excel for Mac (version 15.33 © 2017 Microsoft). From SurveyMonkey™, data were downloaded into Microsoft® Excel format 'xlsx'. Participant data were kept confidential by using a password to protect the document. Data were organised into a single sheet spreadsheet that could then be imported into a statistical analyses program. This allowed all participants data for each week to be seen on one spreadsheet. Training load was reported as a function of volume multiplied by sRPE, with recorded values denoted as AU, as in previous research (19). The magnitude and severity of overuse injuries and illness were reported using the OSTRC methods.

As recommended by previous research on overuse injuries, data from the first questionnaire (Week 1) was removed from analysis (6). Measures of overuse injury and illness included total average prevalence of all overuse injuries and illness, weekly average prevalence of all overuse injuries and illness, average prevalence of substantial overuse injuries and illness and average severity scores. The magnitude and severity of acute injuries was reported using standard injury methods for the recording of acute injuries (5). Measures of acute injury included the number, severity and incidence of injuries.

Statistical analyses were performed using SPSS Statistics software (IBM® SPSS® Statistics, version 25, www.ibm.com). Normality was assessed using the Shapiro-Wilkes test, and it was found that data was not normally distributed. Mann-Whitney u tests were performed to asses for group differences (injured and uninjured groups, and illness and non-illness groups) in terms of demographic information. Spearman's correlation tests were performed to assess the relationship between training load and average prevalence of injury and illness. A Cohen's-d effect size calculation was performed to determine group differences (injured and uninjured groups, and illness and non-illness groups) in terms of acute training load, acute:chronic workload ratio and training parameters for volume and intensity. One-way Friedman's ANOVA and odds ratio calculations were conducted to determine relationships between training load and injury or illness. Statistical significance was accepted as $p < 0.05$.

3.2.6 Ethical considerations

3.2.6.1 Ethical approval

Ethical approval was obtained from the UCT FHS HREC (HREC ref no: 699/2017, Appendix I). The study adhered to the principles of the Declaration of Helsinki (62).

3.2.6.2 Informed consent

All participants were required to sign a written informed consent form (Appendix IV) confirming that they had read and understood the contents of the study information.

3.2.6.3 Confidentiality

To ensure confidentiality, each participant was allocated a reference number against which their data were captured. A master list contained all the names and reference numbers and was stored on a password-protected computer. Participant confidentiality was maintained through the omission of participant names from the data. Only the researcher had access to individual participants' data.
The data were captured and stored on a password-protected computer. A backup of all data was kept on an external hard drive, secured in a locked cabinet. No names were included in the reporting of data to individual participants on completion of the study.

3.2.6.4 Risks to participants

This study presented no additional risks or costs to participants other than those associated with participation in triathlon. The study required commitment in terms of the time needed to complete the required documents once a week for 12 weeks.

3.2.6.5 Benefits to participants

Participants received no direct benefit or monetary compensation for participating in this study. Upon its completion, all participants were provided with a detailed report of the results of the study in the form of an individualised debriefing document and an infographic page (Appendix XI).

3.3 RESULTS

3.3.1 Participant recruitment

41 participants were recruited for the study. The average weekly rate of completion of the questionnaire was 95% (n = 35), and 60% (n = 22) completed all 12 questionnaires. The study sample is summarised in Figure 2.

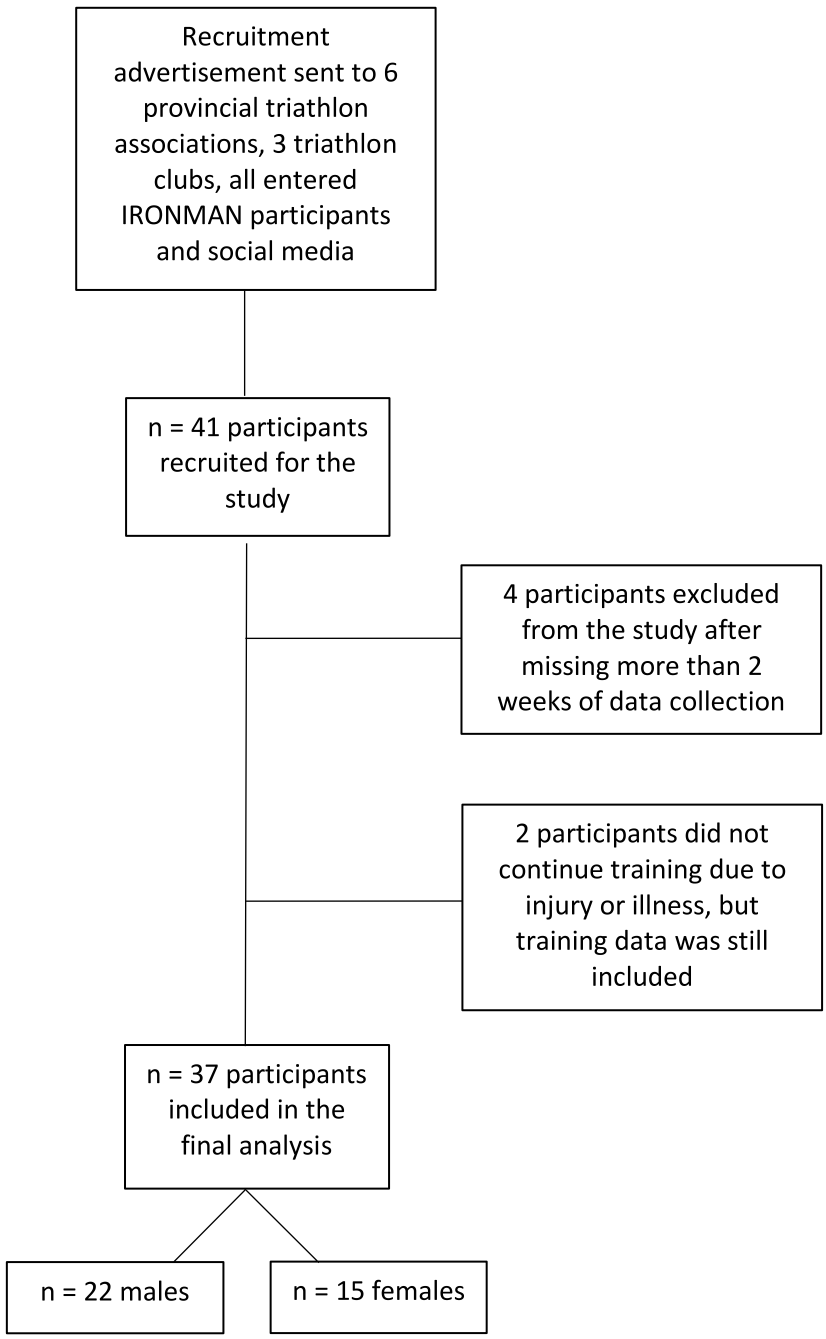

Figure 2: Summary of the study sample.

3.3.2 Descriptive characteristics

All study participants were amateurs or age-group-classified iron-distance triathletes. Twenty-two males and 15 females participated in this study. There were no significant differences in average age, years of training and number of IRONMAN™ events completed between male and female participants. Participant characteristics for the injured and uninjured groups, and the illness and non-illness groups, are shown in Table 3. There were no significant differences in average age, years of training, number of IRONMAN™ events completed, and weekly training hours between each group.

Table 3: Demographics and training characteristics of participants in total, injured group, uninjured group, illness group and non-illness group. Data are presented as mean ± standard deviation.

	Total (n = 37)	Injured (n = 24)	Uninjured (n = 13)	Illness (n = 23)	Non-illness (n = 14)
Age (years)	35 ± 6	36 ± 7	33 ± 5	35 ± 7	35 ± 5
Years in training	5 ± 4	4 ± 3	5 ± 5	4 ± 2	7 ± 5
IRONMAN™ events completed	2 ± 4	2 ± 3	3 ± 5	2 ± 3	3 ± 5
Total weekly training (hours)	12.4 ± 7.1	12.1 ± 8.3	13.0 ± 4.1	12.3 ± 5.2	12.6 ± 9.6
Swimming (hours)	2.3 ± 1.7	2.3 ± 1.2	2.3 ± 1.0	2.2 ± 0.9	2.4 ± 1.4
Cycling (hours)	6.5 ± 3.1	6.6 ± 3.6	6.2 ± 2.1	6.6 ± 1.7	6.2 ± 4.7
Running (hours)	4.0 ± 2.2	3.9 ± 2.6	4.1 ± 1.1	3.8 ± 0.8	4.3 ± 3.4
Other training (hours)	0.9 ± 1.1	0.9 ± 1.1	0.9 ± 1.2	1.1 ± 1.3	0.5 ± 0.7

Three participants did not finish the race. Two participants did not start the race due to injury and/or illness. The average finishing time of the study participants was 13.1 ± 1.4 hours (95% CI: 12.7-13.6). The average swimming time was 1.3 ± 0.2 hours (95% CI: 1.2-1.4); the average cycling time was 6.9 ± 1.4 hours (95% CI: 6.4-7.4); and the average running time was 5.0 ± 0.6 hours (95% CI: 4.8-5.2).

3.3.3 Epidemiology of injury and illness

A summary of the prevalence, incidence and average severity of injuries and illness is shown in Table 4. The prevalence was calculated for the study period as a percentage of the total number of participants that reported an injury or illness. A total of 35 injuries were recorded during the study period, with nine becoming recurrent injuries. Eight of the overuse injuries were classified as substantial overuse injuries. The average weekly prevalence of injury was 19%. The average weekly prevalence of illness was 9%. A summary of the weekly questionnaire completion rate and average weekly prevalence of injury and illness can be seen in table 5.

Table 4: Summary of prevalence, incidence and severity of injuries and illness.

	Illness	Injury			
	New (n = 43)	New (n = 35)	Acute (n = 4)	Overuse (n = 31)	Substantial overuse (n = 8)
Prevalence (%)	62.0	65.0	11.4	88.5	22.9
Incidence (/1 000 hours)	-	9.1	1.0	8.1	2.0
Average severity	51 (mod)	38 (mild)	51 (mod)	36 (mild)	64 (mod)

Severity of overuse injuries or illness is reported using the OSTRC severity scale of 0-100, where 0-25=minor, 26-50=mild, 51-75=moderate, and 76-100=severe (6).

Table 5: Summary of the weekly questionnaire completion rate, and weekly prevalence of injury and illness. Data are presented as weekly sample size (n), and weekly prevalence (%).

Week	Sample size (n = 37)	Weekly prevalence of injury (%)	Weekly prevalence of illness (%)
2	35	28.6	17.1
3	34	20.6	11.8
4	33	27.3	9.1
5	32	15.6	3.1
6	34	23.5	5.9
7	33	6.1	18.2
8	34	23.5	11.8
9	33	27.3	21.2
10	35	25.7	8.6
11	34	20.6	11.8
12	32	21.9	9.4

3.3.4 Injury and illness characteristics

Most injuries occurred during training (n = 25), with eight occurring during competition and two athletes not recording the event during which the injury occurred. Training in one of the disciplines for triathlon (swimming, running or cycling) resulted in the most injuries (n = 20). One injury resulted from other training and 14 injury circumstances were not recorded. Medical attention was sought for training and competition injuries through a physiotherapist (n = 11), a doctor (n = 3) or a biokineticist (n = 1), or else the injury was not recorded (n = 12). No medical attention was sought for eight injuries.

The location of injuries is shown in Figure 3. The most common area of injury was the knee (n = 8). The most common recurring injuries were to the hip and groin (n = 3). Overuse injuries occurred most commonly in the knee (n = 7). There were four acute injuries, one in each of the pelvis/buttock, thigh, knee and lower-leg areas. There were three injury locations that were not recorded.

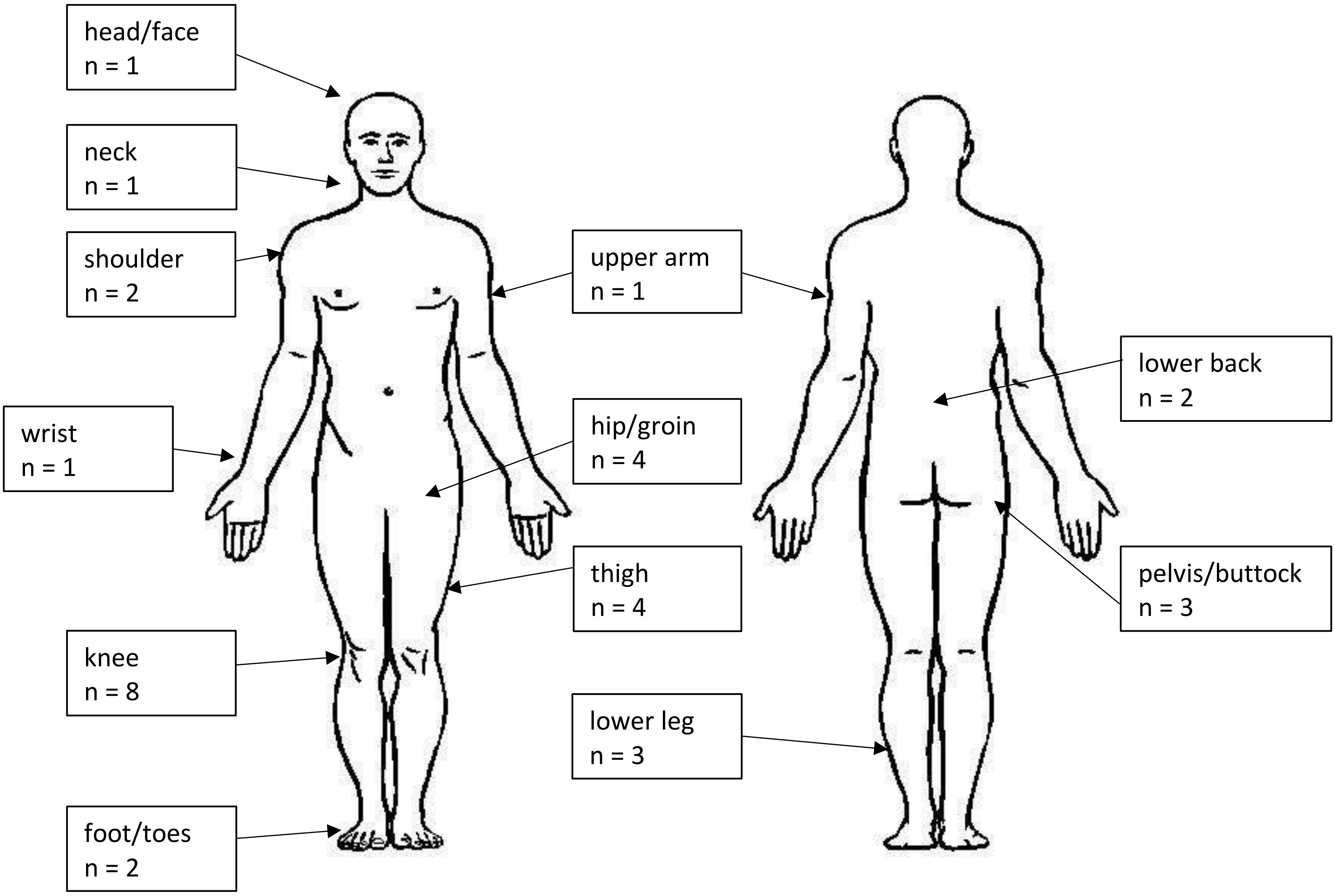

Figure 3 (63): Location of injuries. All new injuries (n = 35) are recorded in blocks.

The locations and severity of injuries according to a time-loss rating scale are presented in Table 6. Most injuries did not result in any time-loss (n = 20). A total of 15 time-loss injuries was reported, with the majority involving minimal severity (1-3 days). The highest number of time-loss injuries (n = 4) involved the knee. Time-loss was not recorded in two injuries.

Table 6: Location and severity of injuries (n = 35) according to time-loss. The red colour represents the highest frequency and the green colour the lowest frequency.

	Light (0 days)	Minimal (1-3 days)	Mild (4-7 days)	Moderate (8-28 days)	Severe (>28 days)
Head/face	0	0	1	0	0
Neck	1	0	0	0	0
Shoulder	0	1	1	0	0
Upper arm	0	1	0	0	0
Wrist	1	0	0	0	0
Lower back	1	0	1	0	0
Pelvis and buttock	2	1	0	0	0
Hip and groin	2	2	0	0	0
Thigh	2	1	1	0	0
Knee	4	4	0	0	0
Lower leg	2	1	0	0	0
Foot/toes	2	0	0	0	0
Not recorded	3	0	0	0	0
Total	20	11	4	0	0

The frequency of each injury type is shown in Figure 4. Injuries that were reported most involved muscle strains (n = 8). In 12 cases, the type of injury was not recorded.

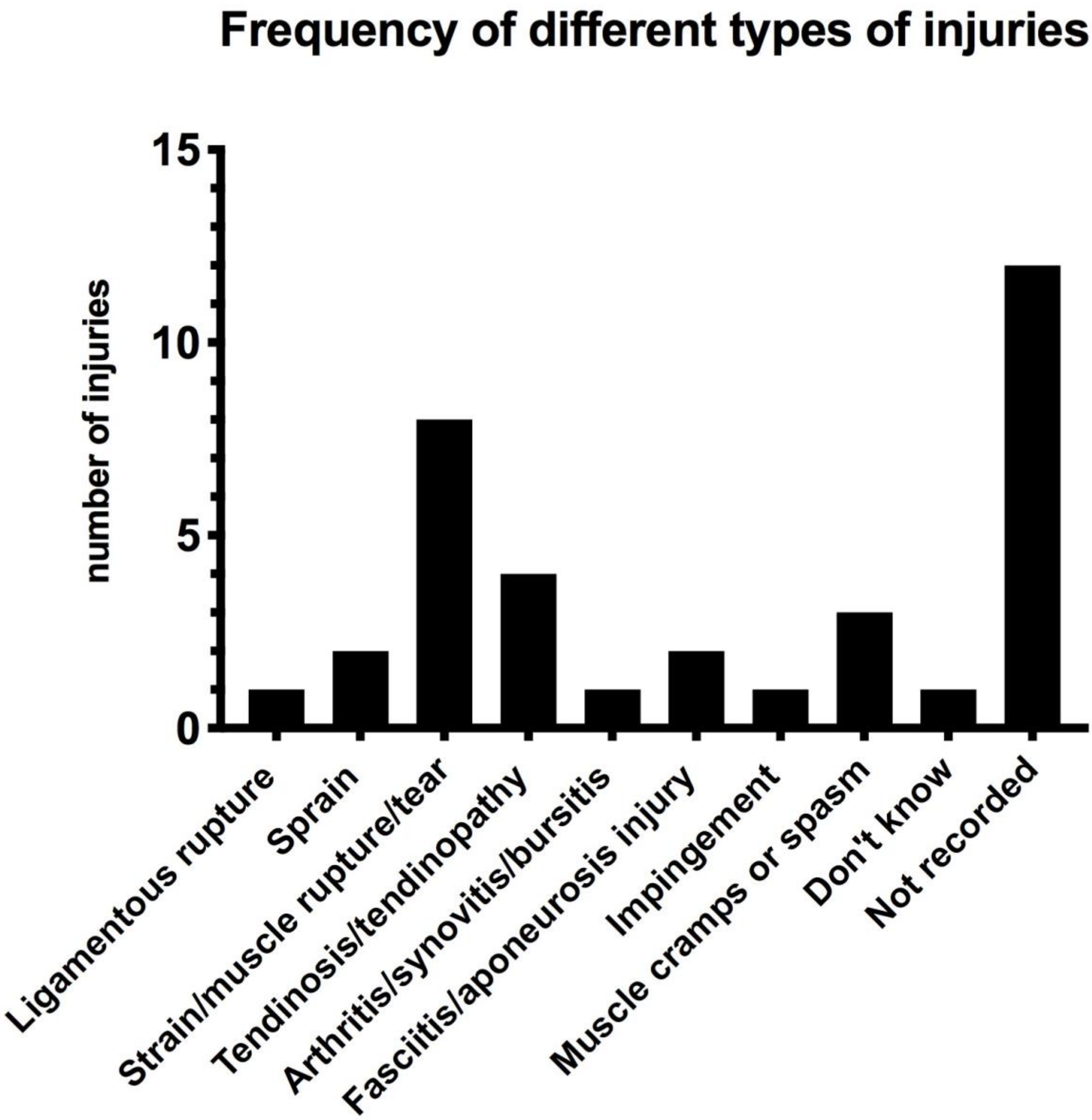

Figure 4: Frequency of each injury type. The figure represents all new injuries (n = 35).

The symptoms and severity of illness according to time-loss is shown in Table 7. The most commonly reported symptoms were fatigue/malaise (n = 12), fever (n = 10) and sore throat (n = 10). Fatigue/malaise accounts for the highest number of time-loss injuries (n = 9). The most common illness severity according to time-loss was 'minimal' (1-3 days).

Table 7: Illness symptoms and severity according to time-loss (n = 47). The red colour represents the highest frequency and the green colour the lowest frequency.

	Light (0 days)	Minimal (1-3 days)	Mild (4-7 days)	Moderate (8-28 days)	Severe (>28 days)
Fever	0	4	5	1	0
Fatigue/malaise	0	9	3	0	0
Swollen glands	0	3	0	0	0
Sore throat	2	5	3	0	0
Blocked nose/running nose/sneezing	0	2	2	0	0
Cough	0	2	0	0	0
Headache	0	1	0	0	0
Nausea	0	1	1	0	0
Vomiting	1	0	0	0	0
Diarrhoea	0	1	0	0	0
Ear symptoms	0	1	0	0	0
Total	3	29	14	1	0

3.3.5 Training load, injury and illness

3.3.5.1 Descriptive reporting of training load

As recommended by research on overuse injuries, data from the first questionnaire (Week 1) was removed from the analysis (6). The average training load, volume and intensity of training for the injured and uninjured groups for the 11 weeks are shown in Table 8. The average training load for each week in the injured and uninjured groups is shown in Figure 5.

A Cohen's-d effect size calculation was performed to determine group differences (injured and uninjured groups) with respect to acute training load, the acute:chronic workload ratio and the training parameters of volume and intensity. There were trivial effect sizes (d = 0.00-0.19) in acute training load, training intensity, cycling, running and other training hours. There was a small effect size (d = 0.2-0.39) in training volume. There were moderate effect sizes (d > 0.4) in acute:chronic workload ratio and swimming hours. These effect sizes indicate that differences in acute training load, acute:chronic workload ratio, and training parameters of volume and intensity were likely not related to getting injured during the study period.

Table 8: Summary of group differences (injured and uninjured groups) in acute training load, acute:chronic workload ratio, training volume and training intensity. Data are presented as weekly mean ± standard deviation.

	Total (n = 37)	Injured (n = 24)	Uninjured (n = 13)	Effect size (d)	Descriptor
Training load (AU)	8 170 ± 3 565	8 354.9 ± 3 466	7 828.7 ± 3 861	-0.09	Trivial
Acute:chronic workload ratio	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.44	Moderate
Training intensity (RPE)	13.1 ± 1.7	12.9 ± 1.9	13.6 ± 1.1	0.16	Trivial
Training volume (hours)	10.5 ± 2.8(7)(7)(7)(7)(7)(7)(7)(7)(7)(7)(7)(6)	10.5 ± 2.7	10.3 ± 3.2	-0.30	Small
Swimming (hours)	1.7 ± 0.8	1.7 ± 0.8	1.4 ± 0.8	0.46	Moderate
Cycling (hours)	4.7 ± 1.8	4.5 ± 1.9	4.3 ± 2.3	0.14	Trivial
Running (hours)	3.1 ± 0.9	3.0 ± 1.2	2.8 ± 1.2	0.16	Trivial
Other training (hours)	0.6 ± 0.5	0.3 ± 0.3	0.2 ± 0.2	0.04	Trivial

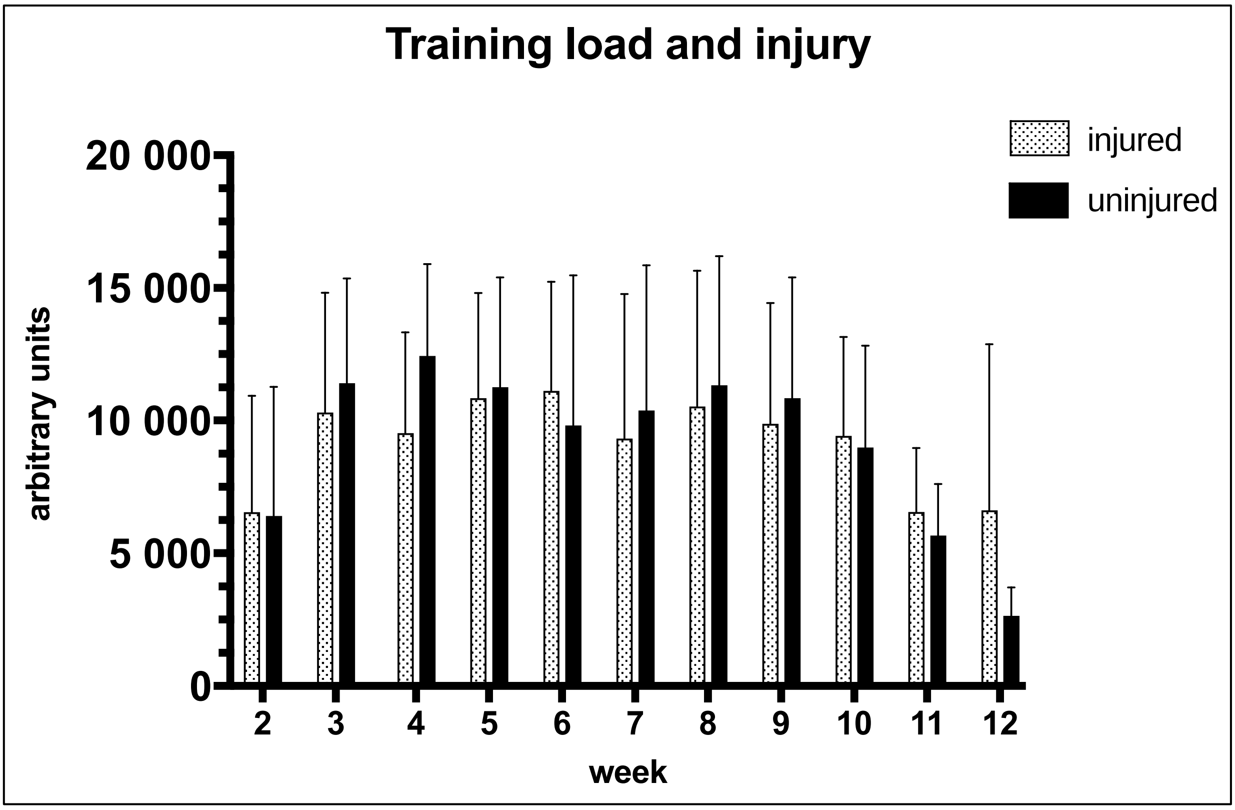

Figure 5: Training load for the injured (n = 24) and uninjured groups (n = 13) reported in arbitrary units (AU). Data are presented as weekly mean ± standard deviation (SD).

The average 11-week training load, volume and intensity of training for the illness and non-illness groups are shown in Table 9. The average training load for each week in the illness and non-illness groups are shown in Figure 6. A Cohen's-d effect size calculation was performed to determine group differences (illness and non-illness groups) in acute training load, the acute:chronic workload ratio and training parameters of volume and intensity. There were trivial effect sizes (d = 0.00-0.19) in acute training load, training intensity and cycling training hours. There were small effect sizes (d = 0.2-0.39) in training volume, and swimming and running hours. There were moderate effect sizes (d > 0.4) in the acute:chronic workload ratio and other training hours. These effect sizes indicate that differences in acute training load, acute:chronic workload ratio, and training parameters of volume and intensity were likely not related to getting an illness during the study period.

Table 9: Summary of group differences (illness and non-illness groups) in acute training load, acute:chronic workload ratio, training volume and training intensity. Data are presented as weekly mean ± standard deviation.

	Total (n = 37)	Illness (n = 23)	Non-illness (n = 14)	Effect size (d)	Descriptor
Training load (AU)	8 170 ± 3 565	8 825 ± 2 585	9 433 ± 3 153	-0.09	Trivial
Acute:chronic workload (ratio)	0.34 ± 0.1	0.4 ± 0.2	0.3 ± 0.1	0.44	Moderate
Training intensity (RPE)	13.1 ± 1.7	13.3 ± 1.1	12.9 ± 2.5	0.16	Trivial
Training volume (hours)	10.5 ± 2.8	10.2 ± 2.8	10.9 ± 2.3	-0.30	Small
Swimming (hours)	1.7 ± 0.8	1.6 ± 0.6	1.6 ± 1.1	-0.24	Small
Cycling (hours)	4.7 ± 1.8	4.6 ± 1.8	4.2 ± 2.4	-0.14	Trivial
Running (hours)	3.1 ± 0.9	3.0 ± 1.0	2.3 ± 1.4	-0.38	Small
Other training (hours)	0.6 ± 0.5	0.3 ± 0.3	0.1 ± 0.1	0.72	Moderate

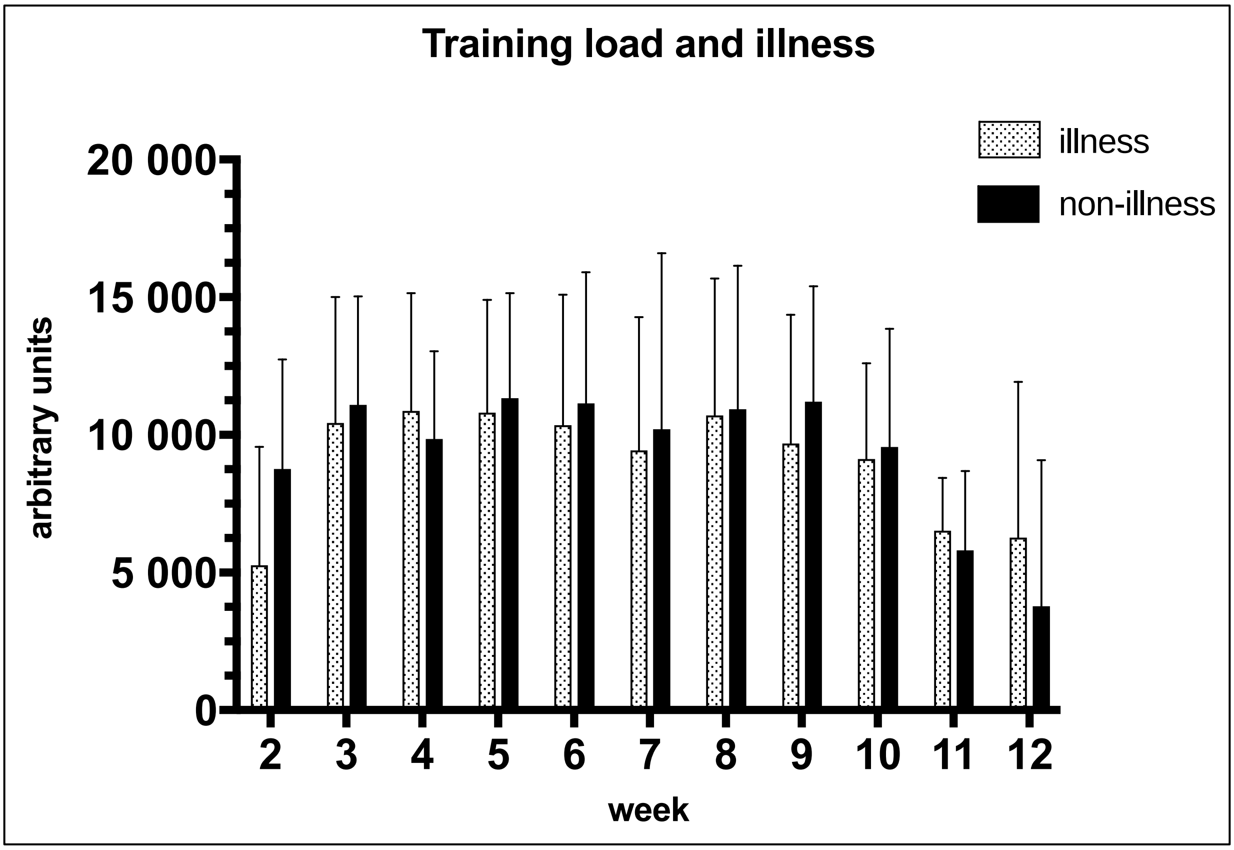

Figure 6: Training load for the illness (n = 23) and non-illness (n = 14) groups reported in arbitrary units (AU). Data are presented as weekly mean ± standard deviation (SD).

3.3.5.2 Training load and injury

The average weekly acute training load and acute:chronic workload ratio for the injured group are shown in Table 10. A Spearman's Rank correlation test showed a significant negative correlation of acute:chronic workload ratio to injury in Week 7, so that as acute:chronic workload ratio decreased, number of injuries increased (r = -0.36, p = 0.04). There was no significant correlation between acute training load and injury.

Table 10: Correlation between injury and training load. A '+' r-value indicates a positive relationship, while a '-' r-value indicates a negative relationship. Training load is presented as weekly mean ± standard deviation for the injured group.

	Acute training load (AU)			Acute:chronic training load (ratio)		
	Mean ± SD	r-value	p-value	Mean ± SD	r-value	p-value
Week 2	6 965 ± 4 526	<0.00	1.00	0.0	-	-
Week 3	11 186 ± 4 433	-0.08	0.64	0.0	-	-
Week 4	9 904 ± 4 198	-0.35	0.05	0.4 ± 0.1	-0.20	0.26
Week 5	11 969 ± 3 678	-0.10	0.61	0.4 ± 0.1	0.05	0.78
Week 6	11 821 ± 4 159	0.15	0.42	0.3 ± 0.1	0.13	0.49
Week 7	10 018 ± 5 773	-0.14	0.45	0.3 ± 0.1	-0.36	0.04*
Week 8	11 559 ± 5 399	-0.07	0.68	0.4 ± 0.1	0.05	0.79
Week 9	10 387 ± 4 435	-0.08	0.66	0.3 ± 0.1	<0.00	0.97
Week 10	9 964 ± 3 922	0.07	0.71	0.3 ± 0.1	0.06	0.73
Week 11	7 381 ± 2 290	0.17	0.35	0.3 ± 0.1	0.22	0.21
Week 12	6 765 ± 6 927	0.18	0.33	0.2 ± 0.2	0.18	0.18

**Values are significant at p<0.05*

The acute training load and acute:chronic workload ratio for the injured and uninjured groups are shown in Table 11. A Friedman's ANOVA was conducted to compare the effect of time on acute training load and acute:chronic workload ratio in the injured and uninjured groups. The main effect of time on acute training load for the injured ($F_{(16, 10)}$ = 31.86, p < 0.01) and uninjured ($F_{(6, 10)}$ = 26.79, p<0.01) groups were significant. The main effect of time on acute:chronic workload ratio for the injured ($F_{(8, 8)}$ = 32.60, p < 0.01) and uninjured ($F_{(18,8)}$ = 24.99, p < 0.01) groups were significant. As a result, there was an increase in acute training load and acute:chronic workload ratio in both groups over time.

Table 11: Summary of training load in the* injured *(n = 24) and uninjured (n = 13) groups. Data are presented as weekly mean ± standard deviation.

	Acute training load (AU)		Acute:chronic training load (ratio)	
	Injury	Uninjured	Injury	Uninjured
Week 2	6 965 ± 4 526	7 243 ± 5 763	-	-
Week 3	11 186 ± 4 433	11 594 ± 5 114	-	-
Week 4	9 904 ± 4 198	12 207 ± 4 208	0.4 ± 0.1	0.4 ± 0.1
Week 5	11 969 ± 3 678	11 570 ± 3 384	0.4 ± 0.1	0.3 ± <0.0
Week 6	11 821 ± 4 159	12 403 ± 5 873	0.3 ± 0.1	0.3 ± 0.1
Week 7	10 018 ± 5 773	12 169 ± 4 990	0.3 ± 0.1	0.4 ± 0.1
Week 8	11 559 ± 5 399	12 778 ± 5 409	0.4 ± 0.1	0.3 ± 0.1
Week 9	10 387 ± 4 435	11 419 ± 575	0.3 ± 0.1	0.3 ± 0.1
Week 10	9 964 ± 3 922	9 581 ± 3 710	0.3 ± 0.1	0.3 ± 0.1
Week 11	7 381 ± 2 290	5 821 ± 1 962	0.3 ± 0.1	0.2 ± 0.1
Week 12	6 765 ± 6 927	2 559 ± 843	0.2 ± 0.2	0.1 ± <0.0

Table 12 shows the acute:chronic workload ratio and acute training load for the injured group organised into subgroups. Odds ratio tests were conducted to determine the likelihood of injury with respect to acute training load and acute:chronic workload ratio. There were no significant differences between acute training loads and acute:chronic workload ratios. Training load was also analysed with regards to early, peak and late seasons, but no significant results were found with respect to odds ratio tests for risk of injury (Appendix IX).

Table 12: Risk factors associated with injury during training. Data are presented as odds ratio (95% CI).

Training load component	Subgroup	Odds ratio (95% CI)
Acute:chronic workload (ratio)	≥ 0.60 (Reference)	1.00
	0.40 to 0.59	0.94 (0.26-3.44)
	0.20 to 0.39	0.99 (0.29-3.43)
	≤ 0.19	1.39 (0.36-5.26)
Acute training load (AU)	≥ 16 000 (Reference)	1.00
	12 000-15 999	1.19 (0.48-2.95)
	8 000-11 999	0.82 (0.35-1.93)
	≤ 8 000	1.05 (0.46-2.44)

3.3.5.3 Training load and illness

The average weekly acute training load and the acute:chronic workload ratio for the illness group are shown in Table 13. A Spearman's Rank correlation test showed that a weak negative correlation between acute training load and illness in Week 2 was significant. As acute training load decreased, the number of illnesses increased ($r = -0.40$, $p = 0.03$). In addition, the weak positive correlation of acute:chronic workload ratio to illness in Week 4 was significant ($r = 0.40$, $p = 0.02$). A positive correlation indicates that, as the acute:chronic workload ratio decreased, number of illnesses decreased.

Table 13: Correlation between illness and training load. A '+' r-value indicates a positive relationship, while a '-' r-value indicates a negative relationship. Training load is presented as weekly mean ± standard deviation for the illness group.

	Acute training load (AU)			Acute:chronic training load (ratio)		
	Mean ± SD	r-value	p-value	Mean ± SD	r-value	p-value
Week 2	5 618 ± 4 489	-0.40	*0.03	0.0	-	-
Week 3	11 088 ± 4 605	<-0.00	0.99	0.0	-	-
Week 4	11 131 ± 4 578	0.12	0.51	0.3 ± 0.1	0.40	0.02*
Week 5	12 173 ± 3 129	-0.05	0.78	0.4 ± 0.1	0.02	0.94
Week 6	11 618 ± 4 533	-0.09	0.61	0.4 ± 0.1	-0.11	0.53
Week 7	9 836 ± 4 630	0.01	0.97	0.3 ± 0.1	-0.13	0.47
Week 8	11 947 ± 5 225	-0.05	0.78	0.3 ± 0.1	-0.06	0.75
Week 9	9 951 ± 4 690	-0.15	0.41	0.4 ± 0.1	-0.10	0.60
Week 10	9 954 ± 3 418	-0.04	0.84	0.3 ± 0.1	0.08	0.63
Week 11	7 124 ± 1 896	0.23	0.20	0.2 ± 0.1	0.30	0.08
Week 12	6 468 ± 6 353	0.27	0.14	0.2 ± 0.1	0.24	0.20

**Values are significant at p<0.05*

The acute training load and the acute:chronic workload ratio for the illness and non-illness groups are shown in Table 14. A Friedman's ANOVA was conducted to compare the effect of time on acute training load and the acute:chronic workload ratio in the illness and non-illness groups. The main effect of time on acute training load for illness ($F_{(14, 10)} = 31.18$, $p < 0.01$) and non-illness ($F_{(8, 10)} = 25.60$, $p < 0.01$) was significant. The main effect of time on the acute:chronic workload ratio for illness ($F_{(17, 8)} = 26.13$, $p < 0.01$) and non-illness ($F_{(9,8)} = 24.62$, $p < 0.01$) was significant. Over time, there was thus an increase in acute training load and the acute:chronic workload ratio in both groups.

Table 14: Summary of training load in the illness (n = 23) and non-illness (n = 14) groups. Data are presented as weekly mean ± standard deviation.

	Acute training load (AU)		Acute:chronic training load (ratio)	
	Illness	Non-illness	Illness	Non-illness
Week 2	5 618 ± 4 489	9 530 ± 4 372	-	-
Week 3	11 088 ± 4 605	11 662 ± 4 612	-	-
Week 4	11 131 ± 4 578	9 483 ± 3 581	0.3 ± 0.1	0.4 ± 0.1
Week 5	12 173 ± 3 129	11 314 ± 4 308	0.4 ± 0.1	0.4 ± 0.1
Week 6	11 618 ± 4 533	12 613 ± 4 886	0.4 ± 0.1	0.3 ± 0.1
Week 7	9 836 ± 4 630	11 950 ± 7 001	0.3 ± 0.1	0.3 ± 0.1
Week 8	11 947 ± 5 225	11 795 ± 5 793	0.3 ± 0.1	0.4 ± 0.1
Week 9	9 951 ± 4 690	11 924 ± 4 775	0.4 ± 0.1	0.3 ± 0.1
Week 10	9 954 ± 3 418	9 694 ± 4 599	0.3 ± 0.1	0.3 ± 0.1
Week 11	7 124 ± 1 896	6 660 ± 2 946	0.2 ± 0.1	0.3 ± 0.1
Week 12	6 468 ± 6 353	4 129 ± 5 950	0.2 ± 0.1	0.2 ± 0.2

Table 15 shows the acute:chronic workload ratio and acute training load for the illness group, which is divided into subgroups. Odds ratio tests were conducted to assess the likelihood of injury in relation to acute training load and the acute:chronic workload ratio. The differences between acute training loads and acute:chronic workload ratios were not significant. Training load was also organised into early, peak and late seasons; however, but no significant results were found with respect to odds ratio tests for risk of illness (Appendix XII).

Table 15: Risk factors associated with illness during training. Data are presented as odds ratio (95% CI).

Training load component	Subgroup	Odds ratio (95% CI)
Acute:chronic workload (ratio)	≥ 0.60 (Reference)	1.00
	0.40 to 0.59	1.47 (0.43-5.04)
	0.20 to 0.39	1.83 (0.57-5.90)
	≤ 0.19	0.49 (0.13-1.81)
Acute training load (AU)	≥ 16 000 (Reference)	1.00
	12 000-15 999	0.67 (0.27-1.64)
	8 000-11 999	0.93 (0.41-2.11)
	≤ 8 000	1.35 (0.60-3.02)

3.3.6 Summary of results

A total of 35 new injuries were reported, with nine injuries becoming recurrent. The proportion of participants who sustained new injuries in this study was 65%, and the incidence was 9 per 1 000 training hours. Overuse injuries accounted for most injuries, with a prevalence of 89% (n = 31) and an incidence of 8 per 1 000 training hours. The average prevalence of illness was 62% (n = 43), while the incidence thereof was of 11 per 1 000 training hours. The weekly average prevalence of injury was 19%, while that of illness was 9%. Most injuries occurred during training, with the knee being the most impacted. The most commonly reported symptoms of illness included fatigue or malaise. Time-loss related to injury and illness was mostly minimal (1-3 days). The severity of overuse injuries was mostly mild (measuring 36 out of 100 on the OSTRC overuse injury severity scale) and of illness was mostly moderate (measuring 51 out of 100 on the OSTRC overuse injury severity scale).

A low acute:chronic workload ratio resulted in an increased risk of injury, as the negative correlation between injury and the acute:chronic workload ratio in Week 7 was significant ($r = -0.36$, $p = 0.04$). A low acute:chronic workload ratio resulted in a decreased risk of illness, as the positive correlation between illness and the acute:chronic workload ratio in Week 4 was significant ($r = 0.40$, $p = 0.02$). A low acute training load resulted in an increased risk of illness, as the negative correlation between injury and acute training load in Week 2 was significant ($r = -0.40$, $p = 0.03$).

A Friedman's ANOVA showed that there was an increase in acute training load and the acute:chronic workload ratio in both the injured and uninjured groups, and the illness and non-illness groups, over time. The effect sizes ($d > 0.4$) in the acute:chronic workload ratio ($d = 0.44$) and swimming hours ($d = 0.46$) between the injured and uninjured groups were moderate. The effect sizes in the acute:chronic workload ratio ($d = 0.44$) and other training hours ($d = 0.72$) were moderate. Odds ratio calculations showed that there were no significant associations between injury or illness and low, moderately low, moderately high or high training loads respectively.

3.4 DISCUSSION

3.4.1 Sample size

This research represents the second prospective cohort study to our knowledge which involves iron-distance triathletes, and uses a new method for recording of overuse injury and illness (1, 8). A small sample (37 participants) took part in our study following the recruitment drive. All triathletes that were included had registered for the IRONMAN™ 2018 African Championship event. Just over 2 000 triathletes competed in the event; however, it was not clear how many were registered at the beginning of the data collection process. This uncertainty may explain the smallness of the sample size, as many triathletes who were not registered at the time of the recruitment drive process may not have received the study advertisement. The triathlon clubs and coaching platforms were contacted weekly for four weeks to get participant recruitment for the study. In the study done by Andersen al (2013) the recruitment drive process was similar to our study, where triathlon clubs and the event organisers were used for recruiting participants. In the prospective study undertaken by Zwingenberger et al (2014), the sample group included 49 amateur participants, a size slightly larger than the number who took part in this study. Two-hundred and seventy-four athletes were invited to participate in the study undertaken by Andersen et al (2013), with the final sample group including 174 participants. In studies on various triathlete populations, participant numbers ranged from 49 to 656 (1, 8, 10, 58). The sample size calculation that was performed prior to our study required 227 participants for 95% statistical power to determine prevalence of overuse injury. The authors recognise that a larger sample size was required for the inference with regards to the greater iron-distance triathlon community to be more statistically significant.

The average weekly response rate for the electronic questionnaire was 95%, and 60% of participants completed all 12 questionnaires. This response rate is similar to that seen in the study by Andersen et al (2013), in which the weekly response rate was 87% and 64% of participants completed all questionnaires. In their study, the methods used to record injury and illness was similar to that used in this study.

3.4.2 Descriptive characteristics

The average age of athletes (35 ± 6 years), years of training (5 ± 4 years) and number of iron-distance triathlons completed (2 ± 4) in our study were similar to those found in previous studies. In the study by Andersen et al (2013), the average age of athletes was 38 ± 9 years, years in training totalled 5 ± 5 and the number of iron-distance triathlons completed was 2 ± 3.

In the study undertaken by Zwingenberger et al (2014), the average age of athletes was 39 years (range = 21-63) and years in training totalled three (range = 0.5-24). However, their participants were not only training for an iron-distance event, and so the similarity between the characteristics of participants in that study and our study should be read with caution.

Our study involved only amateur athletes. In previous studies, elite- and amateur-level participants were observed (1, 8, 10, 58). This distinction may affect the results of our study, since amateur athletes tend to have lower training volumes and a higher risk of injury than elite athletes (1, 8, 13, 34, 64). The findings of our study and its conclusions should be applied to the amateur iron-distance triathlon population and not to elite-level athletes.

3.4.3 Epidemiology of injury and illness

3.4.3.1 Overuse injuries

A total of 35 new injuries were recorded, of which 31 were classified as overuse. Nine of the 35 new injuries became recurrent injuries. Though the average training volume in our study is slightly lower than that recorded by Andersen et al (2013), the prevalence of overuse injury in our study (89%) was similar to that reported in their study (87%). At 8.1 per 1 000 training hours, the incidence of overuse injury is higher in our study than in previous studies on iron-distance athletes; the latter reported incidence rates of between 0.71-1.39 per 1 000 training hours (8, 58). The high incidence and prevalence of overuse injury in our study may be explained by the use of a different method in the recording of overuse injuries. Studies that record only time-loss injuries may exclude injuries that do not prevent the triathlete from training, though such injuries occur often (4, 13). The methods used in our study record injuries in terms of a change in training intensity or volume rather than as a complete cessation of training, and may be better suited to the recording of overuse injuries (23).

Another reason for the high incidence and prevalence of overuse injury in our study could be the difference in the level of athletes who participated. In previous studies, amateur athletes were shown to be at a higher risk of injury than elite athletes (64). Previous studies included participants at both amateur and elite level, whereas this study involved amateur athletes exclusively (1, 8, 58). The high incidence and prevalence rate could also be the result of the relatively low chronic training loads in this study compared to previous studies. Training loads below a specific training threshold may be a risk factor associated with injury (19). This threshold has not been determined for triathlon.

The average weekly prevalence of overuse injury was 19%, which is lower than that recorded by Andersen et al (2013) (54%). This difference may be explained by the smallness of the sample size, resulting in poor statistical power. The ratio of weekly training load to the cumulative weekly training load, described by Gabbett (2016) as the acute:chronic workload ratio, was low in our study. In the study by Gabbett et al (2016), the acute:chronic workload ratio safe zones were provided for team sports such as soccer and rugby, which may have different training loads to endurance sports such as iron-distance triathlon (65). There is currently no research on the use of the acute:chronic workload ratio in endurance sports. The results of our study suggest that, as in team sports, amateur iron-distance triathletes may face an increased risk of injury at smaller acute:chronic workload ratios; however, this supposition cannot be confirmed based on the statistical results in this study.

Substantial overuse injuries may result in a severe reduction in training volume or sports performance, and at worst may result in a complete cessation of training (6). In our study, 'substantial overuse injuries' refers to those injuries that resulted in severe reductions in training load, or complete cessation of training. In the study by Zwingenberger et al (2014), injuries were defined in terms of time-loss, and they may be more closely related to substantial overuse injuries reported in our study. A comparison of these injury rates indicates that iron-distance triathletes may not always miss training days due to injury. Despite a high prevalence of overuse injury, the relatively low prevalence of substantial overuse injury in our study corresponds with the literature, which states that iron-distance triathletes athletes may continue training when injured (4). The incidence of substantial overuse injury in our study was 2 per 1 000 training hours. In the study undertaken by Zwingenberger et al (2014), the incidence of injury (which involved time-loss) was 1.39 per 1 000 training hours (8).

The prevalence of substantial overuse injuries in our study was similar to that found in the study undertaken by Andersen et al (2013). Their study includes participants of elite and amateur levels with relatively higher training loads. The equally high prevalence of substantial overuse injuries in our study may indicate that injuries, when experienced by iron-distance triathletes, are not limited to the elite athletes who train with much higher loads, but are also a result of lower training loads among amateur athletes.

3.4.3.2 Acute injuries

Our study indicates that acute injuries are not very common in iron-distance triathletes. Only four acute injuries were reported in our study, with an incidence of 1.04 per 1 000 hours of training. This figure is similar to that found by Andersen et al (2013), namely 0.97 per 1 000 hours of training.

Andersen et al (2013) used the same acute injury classification system as which was used in our study. The incidence of acute injury in our study is far lower than that reported in other studies, in which rates reached 5.4 per 1 000 hours of training (3, 66). The researchers expected the incidence of injury to be higher than in previous studies owing to the inclusion of injuries that did not result in time-loss. The reason for the lower incidence may therefore be the result of the prospective nature of our study, in which acute injuries were easily differentiated from recurrent overuse injuries. Another reason for the low incidence of acute injury may be the smallness of the sample size. This sample may reflect the experiences of athletes with lower exposure to training hours.

3.4.3.3 Illness

The prevalence of illness in our study was 62%. The average severity of illness was 51 (moderate). No other studies have reported severity of illness using this method. Andersen et al (2013) reported a prevalence of illness of 60% which is similar to this study. It has previously been shown that recreational and sub-elite endurance athletes experience a higher risk of illness than elite athletes (25). The high prevalence of illness in our study may be explained by the inclusion of only amateur athletes. In the study by Andersen at al (2013), they reported an incidence of illness of 5.3 per 1 000 athlete training days (1), whereas our study could not report incidence accurately as the data did not record athlete training days. Due to this data not being available, the authors of the our study did not report on incidence of illness. Future studies should look to ensure that athlete training days are recorded for the purpose of reporting incidence of illness. Another limitation to the reporting of incidence of illness in our study was that we could not differentiate new from recurring illness, which would likely have resulted in very high incidence rates. This was due to the self-reporting method used in our study where illness is diagnosed based on clinical symptoms, and presents a limitation to the reported illness results. A preferred method for diagnosing illness may be the detection of salivary subclinical markers of illness, although this is difficult to use in research due to financial and logistical issues (25).

3.4.4 Injury and illness characteristics

The average severity score of overuse injuries in our study was 36 (mild), which was similar to that found by Andersen et al (2013), namely 29 (mild). With regards to time-loss, most injuries in the present study (n = 20) resulted in no missed training days. These injuries would not have been recorded if the OSTRC severity rating scale was not used, and potentially only 19 injuries would have been recorded during the study period, based on alternative definitions of injury such as medical attention or time-loss.

Having used the above definition of 'injury', the research ensured that 'injury severity' was defined not purely in terms of time-loss or medical attention, but rather in terms of a loss of training volume and/or intensity. Both our study and that undertaken by Andersen et al (2013) may represent a more realistic overview of the burden of overuse injury among iron-distance triathletes. Most overuse injuries in the our study occurred in the knee (n = 8). This finding agrees with previous studies of triathletes that show the knee as being the most commonly injured area (1, 3, 13, 57, 58).

In our study, most injuries occurred during training. In a study on Olympic distance and iron-distance triathletes, Zwingenberger et al (2014) found that competition accounted for most injuries. Their study followed amateur triathletes over a period of 12 months, which allowed the inclusion of multiple competitions in the study (8). Zwingenberger et al (2014) also made use of a time-loss definition of injury. It has been shown that competition results in a greater number of time-loss injuries than training due to the higher intensity of performance (8). While injuries occurring during the event were recorded in our study, time-loss from these injuries was not recorded; as a result, the severity cannot be compared with that noted in previous studies. The higher occurrence of training injuries in our study may be due to the fact that only one iron-distance event took place in the study period.

The main types of injury reported in our study included muscle strains, ruptures or tears. For the most part, the type of injuries that occurred during this study were not reported, so this finding should be compared to other studies with caution. Self-reporting of injury type was used for convenience and these results may be unreliable owing to the risk of incorrect diagnosis. It is unclear why participants did not report the type of injuries. Previous studies have reported that running resulted in the majority of overuse injuries among iron-distance triathletes (12). Most injuries in our study occurred during training for the primary sport (triathlon); however, the specific discipline that resulted in the injury was not included.

In our study, the severity of illness, which was based on missed training days, was mostly minimal (1-3 days lost). The average severity of illness reported by Andersen et al (2013) was similar, with most scores being minimal (1-3 days lost) or mild (4-7 days lost). In our study, the symptoms most often reported were fatigue or malaise, followed by a sore throat. In previous studies on endurance athletes, body pain and symptoms of upper respiratory tract infection (URTI) were most commonly reported (67-69). Fatigue and malaise could be signs of overreaching and/or overtraining; however, these symptoms have also been shown to be preclinical signs of an underlying illness in endurance athletes (25).

Without clinical markers, it is difficult to conclude whether these symptoms were the result of overtraining or an underlying illness (25). The acute:chronic workload ratios in the illness group were very low, so it is reasonable to conclude that underlying illness may have caused the reported symptoms.

3.4.5 Training load, injury and illness

3.4.5.1 Descriptive reporting of training load

A lower training volume has been reported among amateur triathletes than elite athletes (1, 8, 13, 34). Our study showed an average training volume per week of 10.5 hours ± 2.8. This figure is slightly below that reported in previous studies, which showed average per week training volumes of 11.1 and 15.6 hours for amateur and elite athletes, respectively (1, 8, 13, 34). As in previous studies, most training hours were spent on cycling, followed by running and then swimming (1, 4, 8, 36). Participants in both our and previous studies reported training volumes higher than the reported threshold of ten hours, above which the risk of overuse injury increased. High training volumes may explain the high prevalence of injuries in iron-distance triathletes (3, 7). Despite this high prevalence, participants missed very few days of training when injured, suggesting that the cross-training methods used in triathlon may prevent injury, and that overuse injuries (which were the most common injury type in both studies) seldom result in time-loss from training. Triathletes may be able to continue training if they avoid the discipline that resulted in injury, thus minimising aggravation (4, 13).

Our study reported no large effect sizes for average training volume, training intensity, training load or the acute:chronic workload ratio in either group; it is thus difficult to relate the high rate of injury and illness to the average training load of participants in the injury and illness groups, respectively. The incidence of overuse injury in our study was 8.1 per 1 000 training hours. This value is higher than those found in previous studies on iron-distance triathletes (1, 3, 8, 13, 34). The high incidence of injury may be the result of the relatively low training volume witnessed in our study, as a very low volume may increase the risk of injury in triathletes (59). No statistically significant results were able to confirm this theory, and so it ought to be read with caution.

3.4.5.2 Training load and injury

There is currently a dearth of research that measures both external and internal training load among endurance athletes with regards to injury (28). To the researcher's knowledge, no other study apart from the present one has investigated the relationship between internal and external training load and injury in iron-distance triathletes.

The average weekly acute training load that was reported in our study showed no significant correlation with injury. The average weekly acute training load in the injured group was 8 354 ± 3 466 AU. This was higher than that found in a previous study of elite rugby players (19). Gabbett (2016) found that an acute training load of 3000-5000 AU was a risk factor associated with injury. Their study population included elite rugby league players who were followed prospectively over a two-year period. The higher average weekly acute training load that was found in our study, compared to the results of previous studies, may have contributed to the higher incidence of injury. Since this comparison involves different athlete levels and different sport types, this suggestion should be read with caution (19).

Research has shown that the use of the acute:chronic workload ratio may be more useful than the use of only acute training load in the assessment of risk of injury (7, 19). Previous studies that have used the acute:chronic workload ratio researched team sports as opposed to endurance sports (such as iron-distance triathlons) (7, 19). These studies showed that the use of a moderate-low to moderate-high acute:chronic workload ratio of 0.8-1.3 reduced the risk of injury (7, 19). In our study, the average weekly acute:chronic workload ratio in the injured group was 0.3 ± 0.1, putting this group at a high risk of injury. This ratio may explain the high incidence of injury that was observed (7). The average acute:chronic workload ratio in Week 7 showed a significant, but weak, negative correlation with injury, with lower training loads being associated with an increased number of injuries ($r = -0.36$, $p = 0.04$). This finding reinforces the suggestion that lower training loads may be associated with injury, although no definite causation can be concluded. These results also need to be interpreted with some caution, as the optimal range of the acute:chronic workload ratio in endurance sports may differ from that in team sports.

In our study, the training load of the injured group was divided into four categories. These categories represented a low, moderate-to-low, moderate-to-high and high acute training load and acute:chronic workload ratio. Training load was subdivided to identify a training load that might have resulted in an increased risk of injury using odds ratios. This method of identifying risk of injury was used by Malone et al (2017), who reported that a high training load increased the risk of injury in elite soccer players. The results of the study by Malone et al (2017) suggest that there is no significant relationship between low, moderate or high training load and injury. These results differ from those found by Gabbett (2016), in which a very high or very low acute:chronic workload ratio was shown to increase the risk of injury (19).

Our study's authors suggest that the reason why no significant relationship to injury was found is the fact that the training load of the study population may not accurately represent the greater iron-distance triathlon population (1, 8, 13, 34). A larger population size may be necessary for a broader spectrum of training load figures to be obtained, and to make more concrete associations with risk of injury in iron-distance triathletes. No other studies on endurance sport report training load using an acute:chronic workload ratio; as a result, the results of our study cannot be compared with those of previous studies.

3.4.5.3 Training load and illness

In a study undertaken by Schwellnus et al (2016), a consensus statement is given with regards to training load and illness in sport. Absolute values are not given; however, moderate training loads are reported to constitute a reduced risk of illness, and both high and low training loads constitute an increased risk (25). In our study, the only average training load that showed a significant increased risk for illness was in Week 2. The average acute:chronic workload ratio could not be represented in Week 2 as four weeks of data are required to calculate the acute:chronic workload ratio. The average weekly acute training load in Week 2 showed a significant negative correlation with illness: as acute training load decreased, illness increased ($r = -0.40$; $p = 0.03$). The average weekly acute training load in the illness group in Week 2 was 5 618 ± 4 489 AU, well below that in the non-illness group (9 433 ± 3 153 AU). This finding may indicate that low average acute training loads are a risk for illness, which corresponds with that noted by Schwellnus et el (2016). This finding should be read with caution, however, as the low average training load over the 12-week study period did not show significant correlations to illness. The average weekly acute:chronic workload ratio across the study period in the illness group was 0.4 ± 0.2, a value that is low when considered in terms of the known values for increased risk of illness (25). A possible reason for this low acute:chronic workload ratio could be that participants were unable to train hard due to illness; however, since the acute:chronic workload ratio in the non-illness group was lower (0.3 ± 0.1), this conclusion is most likely incorrect.

The average acute:chronic workload ratio in Week 4 showed a significant positive correlation with illness: as acute:chronic workload ratio decreased, illness also decreased ($r = 0.40$, $p = 0.02$). There were no significant differences in the average acute:chronic workload ratio between the illness and non-illness groups in Week 4, and so this result may be the result of random errors that occurred due to the small size of the sample group.

Results from our study suggest that there is no significant relationship between low, moderate or high training load and illness. A possible explanation for this relationship is the fact that significant stress is required for the immune system to adapt to the stressful demands occurring from high-intensity or chronic training loads (4, 14). Not having been exposed to these stressful demands in the past, the body may grow susceptible to infections following strenuous bouts of exercise (45). In our study, chronic training load was measured as part of the acute:chronic workload ratio, rather than as an absolute chronic training load; this method may explain why the results contradict those reported by Schwellnus et al (2016).

3.4.6 Study limitations

The main limitation on our study is the small size of the sample group (37 participants) compared to those used in previous studies. This aspect of the sample group may mean that the burden of injury and illness was underestimated (27). Just over 2 000 athletes competed in the IRONMAN™ event; a larger sample size may thus have yielded a broader and more accurate report of injuries and illnesses that occur during training. The sample size is also significantly smaller than the size needed to calculate statistical power. Another limitation is the fact that, despite overuse injuries presenting the largest injury burden in endurance athletes, only one other study has made use of a method similar to that used in our study to report overuse injuries (1, 6, 27). A comparison of the results of our study with those of previous studies is limited owing to the difference in methodologies (27). Only 60% of participants (n = 22) completed all 12 questionnaires. Missing data may have impacted on the statistical analyses and results (despite similarities with previous research), presenting yet another limitation.

Our study related internal and external training load with injury and illness in iron-distance triathletes; however, no other studies on iron-distance triathletes have posited such a relation. A comparison of these results with those of studies that reported training load and injuries in team sports may be unreliable, as the demands across different sports may vary (7, 19). The athletes who participated in our study were all of amateur level. This characteristic may limit the reliability of a comparison with previous studies, as all previous studies involved both amateur and elite athletes (1, 8, 10, 58). It has been shown that the training and performance patterns of elite athletes may differ from those of amateur athletes. As a result, a comparison of injuries in the amateur athletes who participated in this study with those of elite athletes in other studies may be unreliable.

The questionnaire used in this study did not enable the specification of the sport (swimming, cycling, or running) in which an injury occurred. Previous studies allowed such specification, however, and showed that running injuries accounted for the majority of overuse injuries (1, 3, 8, 12, 13, 36, 57, 58). Reporting of training load in endurance athletes has been investigated mostly using volume measurements. It was recently shown that the use of both internal and external measures of training load may be more useful in the monitoring of athletic training programmes (7). No previous studies have assessed both of these variables in triathletes, meaning comparisons with other studies about training load in iron-distance triathletes are limited (28).

One other previous study on iron-distance triathletes reported incidence of illness per 1 000 athlete training days (1), whilst other studies on iron-distance triathletes did not report incidence of illness. Due to the non-recording of athlete training days, and due to the inability to distinguish new from recurring illness, our study could not report on incidence of illness. Future studies should look to improve on methodologies to enable distinguishing between new and recurring illness, and should ensure that athlete training days are recorded. Another limitation in recording prevalence and incidence of injury and illness was that there was no recording of whether low rates of injury were related to lower training loads from illness. Similarly, there was no recording of whether low rates of illness were related to lower training loads from injury. This should be considered in future studies when designing the method of data recording.

One issue that the researcher faced was the selection bias resulting from the exclusion of potential participants owing to a lack of computer process. With that said, the main methods of communication (including for registration) that concerned the IRONMAN™ event were email and website based. Most IRONMAN™ participants would thus have had periodic, if not regular, access to the internet. In addition, since participants were based in different provinces across South Africa, the chosen method of participation was the most feasible, enabling data collection from as many participants as possible.

CHAPTER 4: SUMMARY AND CONCLUSION

4.1 SUMMARY

Participation in endurance activities, such as iron-distance triathlon, has been associated with overuse injuries owing to the occurrence of repetitive micro-trauma (4). Exposure to the physical and psychological stress related to triathlon training has been associated with an experience of negative health outcomes, such as injury, illness, overtraining and athlete burnout (9). Injury research on triathlon participation is limited to the consideration of Olympic-distance (OD) triathletes, since only one other prospective study on iron-distance triathletes has been undertaken (1). Available research on triathlon participation is limited; however, it is common for triathletes to miss training days due to illness (8). Measures of external and internal load have shown to be useful in the mitigation of the risk of injury and illness in team sports (7, 9). There is currently a dearth of research on training load and its relationship to injury in endurance athletes, such as iron-distance triathletes (28). This study appears to be the only one involving iron-distance triathletes where training load was measured using internal and external measures, helping to identify relationships between training load and injury or illness.

The overall aim of our study was to investigate the impact of training load on injury and illness during a 12-week iron-distance triathlon training period. For this purpose, amateur iron-distance triathletes were monitored for 12 weeks while preparing for an iron-distance event. Based on the evidence provided in this dissertation, the study objectives (as described in Section 1.2.2) were addressed as follows: This study had five specific objectives.

Describe the average weekly training load in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race.

The average acute weekly training load that was reported among study participants was 8 170 ± 3 565 AU. This result shows that iron-distance triathletes may experience a far higher training load than athletes participating in team sports, such as rugby and soccer (7, 19). The acute:chronic workload ratio is reported to be a more accurate reflection of training load. In this study, the overall ratio was 0.3 ± 0.1, which is low compared to the results of previous studies (7).

Describe the total and weekly average prevalence of overuse injury, substantial overuse injury and illness, and the average severity of overuse injuries and illness in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race.

The prevalence of overuse injury was 89% (n = 31), and the incidence was 8 per 1 000 hours of training. The average weekly prevalence of overuse injury was 19%. Substantial overuse injuries exhibited a low prevalence at 23%. This low prevalence may be related to the cross-training methods that are used in the sport (4, 13). Overuse injuries occurred mostly in the knee and predominantly during training. Severity of overuse injuries was mostly mild and did not result in time-loss in any case. The prevalence of illness in this study was 62% (n = 43). The average weekly prevalence of illness was 9%. Severity of illness was mostly moderate, with the number of missed training days being between one and three days in most cases.

Determine the incidence and severity of acute injuries in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race.

The prevalence of acute injury was 11.4% (n = 4), and the incidence of acute injury was 1 per 1 000 training hours. The average severity of acute injuries was moderate.

Determine the average weekly training load threshold above which there is a significantly increased risk of injury or illness in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race.

There were no significant relationships between low, moderate or high training loads and injury or illness. The results of our study showed a high prevalence and incidence of injury, and a high prevalence of illness; however, one cannot relate this point to the training loads observed in our study. The size of the study population may also have contributed to the high injury values that were observed. The sample size (37 participants) was very small. The results yielded from a study of a broader population may have been more accurate. The higher weekly acute training load seen in the present study compared to studies involving rugby and soccer players may indicate that iron-distance triathletes experience higher acute training than team sports (such as soccer and rugby). It is not clear whether an increased risk of injury and illness would result. The low acute:chronic workload ratios observed in this study also cannot be linked to high injury and illness rates. A larger and more heterogeneous sample would be required to identify such relationships in the future.

Determine any associations between the prevalence of overuse injury and risk factors associated with injury (including age, gender, history of previous injuries and triathlon experience) in amateur iron-distance triathletes over a 12-week training period prior to an IRONMAN™ race.

The small sample size meant that thorough analysis of this specific objective was not possible. Future studies should aim to observe a larger population of iron-distance triathletes, assisting thereby in the identification of any associations between the prevalence of overuse injury and known risk factors associated with injury in triathlon.

4.2 CONCLUSION

Our study has shown that iron-distance triathletes are at a high risk of incurring an overuse injury at some stage in their training. The risk of acquiring an illness at some stage in training is also high. This finding may be useful as the first step in the TRIPP protocol, the purpose of which is to describe the burden of injury and illness. The findings of our study highlight the importance of furthering our understanding of factors contributing to the development of injury and illness in iron-distance triathletes to support safe participation and improve performance. Iron-distance triathletes should be able to have access to scientifically proven methods that will reduce the risks associated with injury and illness, ensuring safe participation in triathlon. We cannot currently state with confidence that training load manipulation will reduce these risks, as no significant associations between training load and injury or illness were found in this study.

4.3 RECOMMENDATIONS FOR FUTURE RESEARCH

Future studies should aim to investigate the aetiology of risks, particularly training load, associated with injury and illness in iron-distance triathletes. This will form part of the next step in the TRIPP protocol. This should be investigated in a larger pool of iron-distance triathletes using both internal and external measures. Such findings will produce a more holistic understanding of the effect training load has on the risk of injury and illness during strenuous and chronic endurance training in sports such as iron-distance triathlon than has been established (70).

Prospective methodologies should be the preferred method of data collection, as this method may yield a more accurate representation of the burden of injury and illness (8). When recording overuse injuries in endurance athletes, the researcher recommends the use of the OTRSC reporting method to ensure that overuse and non-time loss injuries are recorded. In the past, time-loss definitions of ‘injury’ have been used, but a definition encompassing injuries that do not prevent the athlete from training is more useful in this population (23). Future studies should also ensure that a full picture of all potential risk factors associated with injury and illness is obtained. These may include intrinsic risk factors such as biomechanical and anatomical factors. Further research into the specific injuries in each sporting discipline within the triathlon event should be performed.

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APPENDIX I: FORMAL ETHICS APPROVAL LETTER

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Building
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07 December 2017

HREC REF: 699/2017

Ms K Buchholtz
Physiotherapy
Health & Rehab
F-floor, OMB

Dear Ms Buchholtz

PROJECT TITLE: THE IMPACT OF TRAINING LOAD ON INJURY AND ILLNESS IN A 12-WEEK TRAINING PERIOD FOR AN IRON-DISTANCE TRIATHLON (MSc-candidate-Mr D Berry)

Thank you for submitting your response to the Faculty of Health Sciences Human Research Ethics Committee received on 27 November 2017.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 December 2018.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

The HREC acknowledge that the student, Darryn Berry will also be involved in this study.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical

HREC 699/2017

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

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Observatory 7925
Telephone [021] 406 6626
Email: shuretta.thomas@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

07 December 2017

HREC REF: 699/2017

Ms K Buchholtz
Physiotherapy
Health & Rehab
F-floor, OMB

Dear Ms Buchholtz

PROJECT TITLE: THE IMPACT OF TRAINING LOAD ON INJURY AND ILLNESS IN A 12-WEEK TRAINING PERIOD FOR AN IRON-DISTANCE TRIATHLON (MSc-candidate-Mr D Berry)

Thank you for submitting your response to the Faculty of Health Sciences Human Research Ethics Committee received on 27 November 2017.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 December 2018.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

The HREC acknowledge that the student, Darryn Berry will also be involved in this study.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical

HREC 699/2017

APPENDIX II: REQUEST FORM FOR DISTRIBUTION OF STUDY ADVERT TO ATHLETES ENTERED INTO THE EVENT

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Department of Health and Rehabilitation Sciences
Division of Physiotherapy;
F45 Old Main Building, Groote Schuur Hospital Observatory, Cape Town, W Cape, 7925
Tel: +27 (0) 21 406 6401/ 6428/ 6628/ 6534 Fax: +27 (0) 21 406 6323

Request to assist in the recruitment of participants for a research study on triathletes participating in the '*IRONMAN™ 2018 African Championships*'

To whom it may concern,

My name is Darryn Berry. I am a qualified physiotherapist, and am studying a part-time m Master's degree in Exercise and Sports Physiotherapy through the University of Cape Town (UCT).

I am doing research on the impact of training load on injury and illness in a 12-week training period for an iron-distance triathlon, and have selected to include participants that will be competing at the IRONMAN™ 2018 African Championship for the study. The study and all its material has been given ethical approval by the University's Human Research Ethics Committee (HREC ref: 699/2017). To assist in the recruitment of athletes into the study, I would like to ask you, the race organisers, for your assistance in distributing an informative study advertisement to athletes entered into the event. *The advertisement could be sent via email to each entered athlete and perhaps published on your official race website.*

Should you be willing to assist in the distribution of this advertisement to athletes via email and on your official race website, I ask that you sign and witness in the space marked below. Your support and willingness to assist in this research project will be greatly appreciated.

Signed: ____________________
Name: ____________________
Date: ____________________

Witnessed: ____________________
Name: ____________________
Date: ____________________

Researcher sign: ____________________
Name: ____________________
Date: ____________________

APPENDIX III: STUDY ADVERTISEMENT

IRONMAN TRAINING LOAD, INJURY, AND ILLNESS RESEARCH PROJECT

Figure 1

12-WEEKS leading up to the IronMan African Champs 2018

weekly online recording of:

 # training load

 # injury

 # illness

<u>**ABOUT THE RESEARCHER:**</u>
Darryn Berry is a qualified Physiotherapist working in Nelspruit, Mpumalanga. He is studying a masters degree in Sports and Exercise Physiotherapy part time through the University of Cape Town (UCT). If you would like to be a part of this study on injury and illness in IronMan athletes, please contact:

darrynberry1@gmail.com
0793426995

Figure 2

ABOUT THIS STUDY...

The aim of this study is to determine the impact of training load on injury and illness in athletes training for an IronMan event. Training for an IronMan triathlon exposes athletes to a high volume of musculoskeletal loading. Overuse injuries are common, and can result in reduced training and/or event performance, as well as time-off from training and/or competition.

WHY IS THIS RESEARCH NEEDED...

- Future development of injury prevention programs
- Identify the risks associated with participation in IronMan triathlon events

APPENDIX IV: INFORMED CONSENT FORM

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Department of Health and Rehabilitation Sciences
Division of Physiotherapy;
F45 Old Main Building, Groote Schuur Hospital Observatory, Cape Town, W Cape, 7925
Tel: +27 (0) 21 406 6401/ 6428/ 6628/ 6534 Fax: +27 (0) 21 406 6323

Informed Consent Document

Dear Participant,

I am a Masters Student in the Division of Physiotherapy at the University of Cape Town (UCT) and will be conducting a research study to determine the impact of training load on injury and illness in a 12-week training period for an iron-distance triathlon. This information will be used to complete my mini-dissertation as partial fulfilment of the MSc Exercise and Sports Physiotherapy program. Ethical approval (HREC Ref: 699/2017) to perform this study has been granted by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town.

Triathlon is becoming a very popular sport among amateur and professional athletes. Iron distance events, such as IRONMAN™, are also increasing in popularity. The training loads of athletes is high when preparing for such an event, and has been shown to put the athlete at risk for an overuse injury. In triathletes, these occur most commonly in the shoulder, lower back, thigh, knee, and lower leg. Injury prevention measures are developed from research projects, and can assist in ensuring safe participation in sports. This study will look to identify the impact of training load on injury and illness of iron distance athletes; and report on any relationship between injury and specific risk factors for injury.

This study will be supervised by Ms. Kim Buchholtz and Dr. Theresa Burgess from the University of Cape Town (UCT). It is important that you read this information sheet carefully before signing consent to participate in this study.

Research Procedure:

You will need to sign a consent form for inclusion in the study. A demographic information form will be sent to you prior to the study, where you will need to fill in details regarding your current training and triathlon/IRONMAN™ history, as well as details regarding any existing or old injuries. Throughout the twelve weeks leading up to the IRONMAN™ 2018 African

Championships, a weekly email will be sent to you linking you to an online questionnaire. This will need to be filled in as accurately as possible. If you are not able to respond to the link, a reminder email will be sent to you after five days. The questionnaire was developed to be as accurate, yet as simple and time-efficient as possible. It shouldn't take longer than 10 minutes to complete. The questionnaires will need to be filled in each week for twelve weeks. The questionnaire will ask you questions relating to any injuries or illnesses you may have obtained in the week during training or participating in an event. If you did not sustain an injury or illness, the questionnaire will still need to be completed. The questionnaire also contains questions relating to your weekly training load; more specifically how long you trained for in each discipline (swimming, running, cycling), and how hard you rated each session to be. The amount of time you spent doing other forms of training such as strength or core work will also be recorded. The final questionnaire will be submitted after your IRONMAN™ event as this data will be included in the study. The questions are all self-explanatory.

Confidentiality

All the information which you provide regarding injuries, illnesses, and training loads will be kept completely private. No personal details will be revealed in the analysis and report of the data, and once the data analysis has been done, all identifying data linking you to the results will be deleted permanently.

Risks to participants

This study imposes no additional risks or costs to participants other than those associated with participation in triathlon as a sport. The study does require a commitment in terms of time to complete the required documents once a week for 12 weeks. The purpose of this study is to record the epidemiology of injuries and illness, and so it is the participants own responsibility to seek treatment for any injuries or illnesses sustained during their training.

Benefits to participants

There is no direct benefit or monetary compensation to individual participants from participating in this study. At the completion of the study, all participants will be provided with a detailed report of the results of the study in the form of a debriefing document.

****If at any time you have any ethical concerns or questions about the rights or welfare of patients, you can contact the following personnel for assistance. You are assured that all enquiries will remain confidential.**

Prof. Marc Blockman (Human Research Ethics Committee)
Telephone: 021 406 6492
Email: marc.blockman@uct.ac.za
Physical Address: Faculty of Health Sciences Human Research Ethics Committee, Old Main Building of Groote Schuur Hospital, Observatory, 7925

****If at any time you have any questions about the study, you can contact any of the individuals listed below. You are assured that all enquiries will remain confidential.**

Mr. Darryn Berry (Researcher)
Telephone: 0793426995
Email: darrynberry1@gmail.com
Physical Address: 30 Orange Street, West Acres, Nelspruit, Mpumalanga, 1201

Ms. Kim Buchholtz (Supervisor)
Telephone: 0214606135
Email: kim.buchholtz@uct.ac.za
Physical Address: Division of Physiotherapy, Department of Health and Rehabilitation Sciences, University of Cape Town, Groote Schuur Hospital, Anzio Road, Observatory, 7925

Dr. Theresa Burgess (Supervisor)
Telephone: 0214066171
Email: theresa.burgess@uct.ac.za
Physical Address: Division of Physiotherapy, Department of Health and Rehabilitation Sciences, University of Cape Town, Groote Schuur Hospital, Anzio Road, Observatory, 7925

Please complete and sign the following information to give consent for participation in this study:

I ______________________________ have had adequate time to read the information provided to me regarding this study. I understand what is required of me and I have had all my questions answered. By signing below, I grant consent to participate in this study and acknowledge that participation is voluntary. Furthermore, I acknowledge that I can withdraw my consent at any stage with no negative consequences.

All information recorded during this study will remain confidential, and no participants will be identified in the event of future publication. Your signature is further confirmation that you are aware of the possible risks involved in triathlon participation, and that the researcher and University of Cape Town cannot be held responsible for injury/death resulting from participating in IRONMAN™.

Signed: ____________________
Name: ____________________
Date: ____________________

Witnessed: ____________________
Name: ____________________
Date: ____________________

Researcher sign: ____________________
Name: ____________________
Date: ____________________

APPENDIX V: DEMOGRAPHIC INFORMATION FORM

Please fill in the following information:

Name:

☐

Age:

☐

Sex:

☐

Years of experience in triathlon training (Olympic distance, half-iron distance, or iron distance):

☐

Level of competition (mark with an 'x'):

☐ amateur / age group athlete

☐ professional athlete

What was your primary sport before starting triathlons (mark with an 'x'):

Swimming ☐

Cycling ☐

Running ☐

Number of IRONMAN™ or other iron distance events completed:

☐

When was the last time you competed in an IRONMAN™ or other iron distance event (months):

[ ]

[In the past 4 weeks, what is your average weekly amount of training hours:]

Total [ ]

Swimming [ ]

Cycling [ ]

Running [ ]

Other [ ] Specify [ ]

Have you missed training in the past 6 months due to injury:

[ ] yes, than how long did you not train for (weeks) [ ]

[ ] no

[Have you had any previous shoulder problems in the past 12 months (mark with an 'x')?]
"Shoulder problems" refers to pain, ache, stiffness, feelings of instability, or other complaints from one or both shoulders.

[ ] yes left [ ] right [ ]

[ ] no

[Have you had any previous lower back problems in the past 12 months (mark with an 'x')?]
"Lower back problems" refers to pain, ache, stiffness, or other complaints located in the lower part of your back.

[ ] yes

[ ] no

[Have you had any previous knee problems in the past 12 months (mark with an 'x')?]
"Knee problems" refers to pain, ache, stiffness, feelings of instability, swelling, locking, or other complaints from one or both knees.

☐ yes   left ☐   right ☐

☐ no

[Have you had any previous thigh problems in the past 12 months (mark with an 'x')?]
"Thigh problems" refers to pain, ache, cramps, stiffness, or other complaints in one or both thighs.

☐ yes   left ☐   right ☐

☐ no

[Have you had any previous lower leg problems in the past 12 months (mark with an 'x')?]
"Lower leg problems" refers to pain, ache, cramps, stiffness, or other complaints located in your leg between the knee joint and the ankle joint. This includes your calf muscles, Achilles tendon, and shins.

☐ yes   left ☐   right ☐

☐ no

APPENDIX VI: SECTION A: OSTRC QUESTIONNAIRE ON HEALTH PROBLEMS

Section A: Health Problems

Please answer all questions regardless of whether or not you have experienced health problems in the ***PAST WEEK***. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

If you have several illness or injury problems, please refer to the one that has been your worst problem this week. You will have a chance to register other problems at the end of the questionnaire.

Question 1

*Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the **PAST WEEK**?*

- ☐ Full participation without health problems
- ☐ Full participation, but with injury/illness
- ☐ Reduced participation due to injury/illness
- ☐ Cannot participate due to injury/illness

Question 2

*To what extent have you reduced you training volume due to injury, illness or other health problems during the **PAST WEEK**?*

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3

*To what extent has injury, illness or other health problems affected your training/competition performance during the **PAST WEEK**?*

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4
To what extent have you experienced symptoms/health complaints during the ***PAST WEEK****?*

- ☐ No symptoms/health complaints
- ☐ To a mild extent
- ☐ To a moderate extent
- ☐ To a severe extent

Question 5
Is the health problem referred to in the questions above an-
injury *(any musculoskeletal complaint that has caused a reduction in the level of training or competition) or an-*
illness (*any health problem that is not related to the musculoskeletal system, for example respiratory tract infections, gastrointestinal infection, and influenza, etc*).

- ☐ Injury
- ☐ Illness
- ☐ I have not had an injury/illness

Question 6 - Injury Area
Please select box that best describes the location of your most severe injury. If the injury involves several locations please now select the main area of symptoms. You will have a chance to record other injuries at the end of the questionnaire.

- ☐ Head/face
- ☐ Neck
- ☐ Shoulder (including clavicle)
- ☐ Upper arm
- ☐ Elbow
- ☐ Forearm
- ☐ Wrist
- ☐ Hand/fingers
- ☐ Chest/ribs
- ☐ Abdomen
- ☐ Thoracic spine/upper back
- ☐ Lumbar spine/lower back
- ☐ Pelvis and buttock
- ☐ Hip and groin
- ☐ Thigh
- ☐ Knee
- ☐ Lower leg
- ☐ Ankle
- ☐ Foot/toes
- ☐ Other

Question 7 - Illness Symptoms

*Please check the boxes corresponding to the most severe symptoms you have experienced during the **PAST WEEK**. You may select several alternatives.*

- ☐ Fever
- ☐ Fatigue/malaise
- ☐ Swollen glands
- ☐ Sore throat
- ☐ Blocked nose/running nose/sneezing
- ☐ Cough
- ☐ Breathing difficulty/tightness
- ☐ Headache
- ☐ Nausea
- ☐ Vomiting
- ☐ Diarrhoea
- ☐ Constipation
- ☐ Fainting
- ☐ Rash/itchiness
- ☐ Irregular pulse/arrhythmia
- ☐ Chest pain/angina
- ☐ Abdominal pain
- ☐ Other pain
- ☐ Numbness/pins and needles
- ☐ Anxiety
- ☐ Depression/sadness
- ☐ Irritability
- ☐ Eye symptoms
- ☐ Ear symptoms
- ☐ Symptoms from urinary tract/genitalia
- ☐ Other. Please specify ______________________________________

Question 8

*Have you lost one or more days of training/competition during the **PAST MONTH** due to this injury, illness or other health problem?*

☐ No
☐ 1-3 days
☐ 4-7 days
☐ 8-28 days
☐ >28 days

APPENDIX VI: SECTION B: ADDITIONAL QUESTION OSTRC QUESTIONNAIRE ON HEALTH PROBLEMS – TRAINING/COMPETITION VOLUME

<u>Section B: Training</u>

Question 9

*Please report your total number of training hours for the **PAST WEEK**.*

Total ☐

Swimming ☐

Cycling ☐

Running ☐

Other training:

Core strengthening ☐

Body weight or resistance or plyometric lower limb training ☐

Body weight or resistance or plyometric upper limb training ☐

Other modes of cardiovascular training: elliptical; rowing; arm cycle ergometer; etc ☐

Other functional training activities: squash; surfing; tennis; etc ☐

Question 10

*Please report your average rating of perceived exertion (RPE) for your training during the **PAST WEEK**.*

Swimming ☐

Cycling ☐

Running ☐

Other training:

Core strengthening ☐

Body weight or resistance or plyometric lower limb training ☐

Body weight or resistance or plyometric upper limb training ☐

Other modes of cardiovascular training: elliptical; rowing; arm cycle ergometer; etc

Other functional training activities: squash; surfing; tennis; etc

0 did not train
6 very, very light
7
8 very light
9
10 fairly light
11
12 somewhat hard
13
14 hard
15
16 very hard
17
18 very, very hard
19

Question 11
How many hours of competition have you completed during the ***PAST WEEK****?*

Please report your average rating of perceived exertion (RPE) for your competition during the ***PAST WEEK****.*

0 did not compete
6 very, very light
7
8 very light
9
10 fairly light
11
12 somewhat hard
13
14 hard
15
16 very hard
17
18 very, very hard
19

APPENDIX VI: SECTION C: ADDITIONAL QUESTION TO OSTRC QUESTIONNAIRE ON HEALTH PROBLEMS – ACUTE INJURIES

Section C: Injury Classification

Please report whether you have had injuries or other health problems causing reduced training or racing during the ***PAST WEEK***. Please answer "yes" to this question even if you have already given us information on the injury through previous questions in this survey.

Question 12
Illness/Injuries

□ Yes, I have been injured
□ No, I have trained 100%

The purpose with this question is to clarify what type of injury you have. Please try to classify the injury type, even if you have not seen a doctor to obtain a specific diagnosis.

Question 13
Injury type

□ Concussion (symptoms like disorientation, dizziness, loss of memory, nausea or vomiting due to a blow to the head)
□ Fracture (traumatic) (broken bone caused by sudden impact)
□ Stress fracture (overuse) (fracture in a weight bearing bone caused by repetitive stress (e.g. running), a stress fracture in one of the small bones in the foot will typically cause severe pain at the beginning of a run, moderate pain during the run and severe pain at the end and after the run)
□ Other bone injuries
□ Dislocation, subluxation (the total or partial displacement or misalignment of bones in a joint, most often caused by a sudden impact to the joint)
□ Tendon rupture (tearing of a tendon that occurs when the forces placed upon the tendon exceed its tensile strength)
□ Ligamentous rupture (tearing of the bands of fibrous tissue connecting bones or cartilages, serving to support and strengthen joints)
□ Sprain (wrenching or twisting of a joint, with partial rupture of its ligaments, accompanied by severe pain, impaired function, swelling, heat and discoloration of the skin)
□ Lesion of meniscus or cartilage (injuries of meniscus (knee) or joint surfaces)
□ Strain/muscle rupture/tear
□ Contusion/haematoma/bruise

□ Tendinosis/tendinopathy (all non-inflammatory and inflammatory conditions affecting a tendon, "tendinitis")
□ Arthritis/synovitis/bursitis (inflammation of any part of a joint or structures near the joint, characterized by pain on movement, tenderness, heat and swelling)
□ Fasciitis/aponeurosis injury (inflammation or injury of a sheet like tendinous expansion, e.g. plantar fasciitis)
□ Impingement (compression of a nerve, blood vessel, tendon, ligament or muscle through a constricted space, e.g. sciatica)
□ Laceration/abrasion/skin lesion
□ Dental injury/broken tooth
□ Nerve injury/spinal cord injury
□ Muscle cramps or spasm
□ Other
□ Don´t know

Question 14
Who made the diagnosis?

□ Doctor
□ Physical therapist
□ Other health professional
□ Coach
□ Made the diagnosis myself

Question 15
Have you had this type of injury before?

□ No, this is a new injury
□ Yes, this is an ongoing injury
□ Yes, this is a worsening of an ongoing injury
□ Yes, this is recurrence of a previous, fully recovered injury

Question 16
How long since the last time you had this particular injury? (months)

Question 17
Injury onset (current injury)

□ Gradual onset
□ Sudden onset

Question 18
Was the injury caused by a specific inciting event? (Collision, fall, rolled ankle, etc.)

□ Yes
□ No

Question 19
Under what circumstances?
□ Training
□ Competition
□ Other

Question 20
Describe other circumstance?

Question 21
What kind of training?

□ Training in primary sport (swim, cycle, or run)
□ Alternative training

Question 22
Type of alternative training?

Question 23
Describe the injury onset as briefly and precisely as possible (situation/mechanism) (e.g. fell off bike, hit by car, twisted ankle, bumped knee, etc…)

Question 24
Did you seek medical attention?

□ No
□ Doctor
□ Physiotherapist
□ Other

Question 25
What kind of other medical attention?

Question 26
Have you experienced any other illnesses, injuries or other health problems during the ***PAST WEEK****?*

□ Yes
□ No

APPENDIX VII: VALIDATION LETTER FOR THE PANEL OF EXPERTS

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Department of Health and Rehabilitation Sciences
Division of Physiotherapy;
F45 Old Main Building, Groote Schuur Hospital Observatory, Cape Town, W Cape, 7925
Tel: +27 (0) 21 406 6401/ 6428/ 6628/ 6534 Fax: +27 (0) 21 406 6323

Request for assistance: validation of the questionnaire titled 'OSTRC Health Problems Questionnaire'

Dear *(insert name)*

I am a qualified physiotherapist, and am studying a part-time Master's degree in Exercise and Sports Physiotherapy through the University of Cape Town (UCT). I am doing research on the impact of training load on injury and illness in a 12-week training period for an iron-distance triathlon, and have selected to include participants that will be competing at the IRONMAN™ 2018 African Championships for the study. I am writing to you to kindly request assistance with the validation of a questionnaire, the Oslo Sports Trauma Research Centre (OSTRC) Health Problems Questionnaire, to record injuries and illness in IRONMAN™ triathletes. The study and all its material has been given ethical approval by the University's Human Research Ethics Committee (HREC ref: 699/2017).

Iron distance triathlons such as IRONMAN™ are increasing in popularity among the general and elite population, and so has the need to prevent injuries from participation in the sport. Triathletes have shown to continue training despite being injured, and so the previous methods of injury surveillance such as using time-loss to define an injury are not completely valid. It is for this reason that the OSTRC Overuse Injury Questionnaire was developed in 2013 to better define the impact of overuse injury on athletes, so that severity of overuse injury is not calculated as time-loss from sport, but rather on a scale from 0-100 reflecting the impact of injury on sports participation, training volume, and sports performance. The OSTRC Overuse Injury Questionnaire was shown to be a valid and reliable tool for comparison of overuse injuries occurring in athletes across five different sporting codes. It was also successfully used for continuous monitoring and reporting of overuse injuries in a study done on iron distance athletes of various levels competing in an iron distance event. The OSTRC Questionnaire on Health Problems was developed as an updated version of the original overuse injury questionnaire. It proved valid and sensitive for continuous injury recording in a large heterogeneous group of elite athletes in Europe. These questionnaires have not yet been validated in a South African context, and so a feasibility study of the questionnaire will be done to test the content and construct validity within a South African sample of participants.

The questionnaire consists of 3 sections: Section A is the registration of health problems according to the new method for overuse injury recording, Section B is for recording of training load in the week, and Section C for the recording of injury details regarding acute injuries. The aims of the questionnaire are specific for answering the study objectives, which are summarized as follows:

- Determine the average training load during a 12-week preparation for the IRONMAN™ event.
- Determine the average prevalence and severity of overuse injuries, and illness during a 12-week preparation for the IRONMAN™ event.
- Determine the incidence and severity of acute injuries during a 12-week preparation for the IRONMAN™ event.

As a recognised *(insert specific expertise)* and an expert in the field of sports and exercise, I want to request your assistance with the validation of the content of the questionnaire. Specifically, we would ask you to look at the following:

- if the questionnaire is relevant and important for recording training load, injury, and illness in a population of endurance athletes.
- if the questions are clear and easy to understand.
- additionally, please could you provide any comments if you feel there are any question which you feel may be absent from the questionnaire.

There is a comments box below each question where you may provide any comments you feel are necessary. The questionnaire is pages and should take two hours to review. Please note that participants will only be required to answer necessary questions as a skip logic will skip unnecessary questions. As a validator, you will not be a study participant and your feedback will be treated confidentially.

If you agree to assist, I will email the questionnaire to you. Your feedback will be valuable and greatly appreciated. If possible, please could you return any feedback before *(insert date)*. Please contact me should you have further questions or should you be unable to assist with the validation process.

My and my supervisors contact details are as follows:

Darryn Berry
0793426995
darrynberry1@gmail.com

Ms. Kim Buchholtz (Supervisor)
0214606135
kim.buchholtz@uct.ac.za

Dr. Theresa Burgess (Supervisor)
0214066171
theresa.burgess@uct.ac.za

APPENDIX VIII: VALIDATION DOCUMENT FROM EXPERT 1

Section A: Health Problems

Please answer all questions regardless of whether or not you have experienced health problems in the past week. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

If you have several illness or injury problems, please refer to the one that has been your worst problem this week. You will have a chance to register other problems at the end of the questionnaire.

Question 1
Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the past week?

- ☐ Full participation without health problems
- ☐ Full participation, but with injury/illness
- ☐ Reduced participation due to injury/illness
- ☐ Cannot participate due to injury/illness

Comments: Good question and pertinent too. Are you going to ask each athlete to describe their weekly training schedule to you??

Question 2
To what extent have you reduced your training volume due to injury, illness or other health problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Comments: Maybe include a % value behind minor, moderate and major; ie: 25%, 50% and 75%

Question 3
To what extent has injury, illness or other health problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent

☐ Cannot participate at all

Comments: **Please see comment above**

Question 4

To what extent have you experienced symptoms/health complaints during the past week?

☐ No symptoms/health complaints
☐ To a mild extent
☐ To a moderate extent
☐ To a severe extent

Comments: **Again, possibly quantify mild, moderate and severe**

Question 5

Is the health problem referred to in the questions above an injury or an illness?

☐ Injury
☐ Illness
☐ I have not had an injury/illness

Comments:

Question 6 - Injury Area

Please select box that best describes the location of your injury. If the injury involves several locations please now select the main area. You will have a chance to record other injuries at the end of the questionnaire.

☐ Head/face
☐ Neck
☐ Shoulder (including clavicle)
☐ Upper arm
☐ Elbow
☐ Forearm
☐ Wrist
☐ Hand/fingers
☐ Chest/ribs
☐ Abdomen
☐ Thoracic spine/upper back
☐ Lumbar spine/lower back
☐ Pelvis and buttock
☐ Hip and groin

- ☐ Thigh
- ☐ Knee
- ☐ Lower leg
- ☐ Ankle
- ☐ Foot/toes
- ☐ Other

Comments: I would seriously recommend including either right/ left sides OR dominant/non-dominant side

Question 7 - Illness Symptoms

Please check the boxes corresponding to the major symptoms you have experienced during the past week. You may select several alternatives.

- ☐ Fever
- ☐ Fatigue/malaise
- ☐ Swollen glands
- ☐ Sore throat
- ☐ Blocked nose/running nose/sneezing
- ☐ Cough
- ☐ Breathing difficulty/tightness
- ☐ Headache
- ☐ Nausea
- ☐ Vomiting
- ☐ Diarrhoea
- ☐ Constipation
- ☐ Fainting
- ☐ Rash/itchiness
- ☐ Irregular pulse/arrhythmia
- ☐ Chest pain/angina
- ☐ Abdominal pain
- ☐ Other pain
- ☐ Numbness/pins and needles
- ☐ Anxiety
- ☐ Depression/sadness
- ☐ Irritability
- ☐ Eye symptoms
- ☐ Ear symptoms
- ☐ Symptoms from urinary tract/genitalia
- ☐ Other. Please specify ____

Comments: Good

Question 8

Have you lost one or more days of training/competition during the past week due to injury, illness or other health problems?

- ☐ No
- ☐ 1-3 days
- ☐ 4-7 days
- ☐ 8-28 days
- ☐ >28 days

Comments: Good

Section B: Training

Question 9

Please report your total number of training hours for the past week. Include all forms of training together (swim, bike, run, strength/core/balance/other).

Comments: **Possibly provide a drop down menu describing activity so that person completing questionnaire just puts in the hours and a total gets summed up. This way you can remove questions 10, 12, 14 and 16.**

Question 10

How many hours did you swim during the past week?

Comments: **See comment in question 9**

Question 11

Please report your average rating of perceived exertion for your swim training during the past week.

6
7 very, very light
8
9 very light
10
11 fairly light
12
13 somewhat hard
14
15 hard
16
17 very hard
18
19 very, very hard
20

<u>Comments:</u> again, I would combine this question with question 13,15 and 17. I.e.: create a question stating, please report your avregae rating of perceived training during the past week for:

1. **Swimming**
2. **Cycling**
3. **Running**
4. **Core/balance/gym etc**

Question 12

How many hours did you cycle during the past week?

<u>Comments:</u> See comment under question 9

Question 13

Please report your average rating of perceived for your bike training during the past week.

6
7 very, very light
8
9 very light
10
11 fairly light
12
13 somewhat hard
14
15 hard
16
17 very hard
18
19 very, very hard
20

<u>Comments:</u> See comment under question11

Question 14

How many hours did you run during the past week?

<u>Comments:</u> see comment under question 9

Question 15

Please report your average rating of perceived exertion) for your run training during the past week.

6	
7	very, very light
8	
9	very light
10	
11	fairly light
12	
13	somewhat hard
14	
15	hard
16	
17	very hard
18	
19	very, very hard
20	

<u>Comments:</u> see comment under question 11

Question 16

How many hours did you do core/strength/balance/other exercise during the past week?

<u>Comments:</u> see comment under question 9

Question 17

Please report your average rating of perceived exertion (for your core/strength/balance/other exercise training during the past week.

0	
6	very, very light
7	
8	very light
9	
10	fairly light
11	
12	somewhat hard
13	
14	hard
15	
16	very hard
17	
18	very, very hard
19	

Comments: see comment under question 11

Question 18

*How many hours of **racing** have you completed during the past week?*

Comments: Good – possibly include distance raced as well?

Section C: Acute injuries

Please report whether you have had injuries or other health problems causing reduced training or racing during the ***PAST WEEK.*** Please answer "yes" to this question even if you have already given us information on the injury through previous questions in this survey.

Question 19
Illness/Injuries

- ◻ Yes, I have been injured
- ◻ No, I have trained 100%

Comments: Good!

The purpose with this question is to clarify what type of injury you have. Please try to classify the injury type, even if you have not seen a doctor to obtain a specific diagnosis.

Question 20
Injury type

- ◻ Concussion (symptoms like disorientation, dizziness, loss of memory, nausea or vomiting due to a blow to the head)
- ◻ Fracture (traumatic) (broken bone caused by sudden impact)
- ◻ Stress fracture (overuse) (fracture in a weight bearing bone caused by repetitive stress (e.g. running), a stress fracture in one of the small bones in the foot will typically cause severe pain at the beginning of a run, moderate pain during the run and severe pain at the end and after the run)
- ◻ Other bone injuries
- ◻ Dislocation, subluxation (the total or partial displacement or misalignment of bones in a joint, most often caused by a sudden impact to the joint)
- ◻ Tendon rupture (tearing of a tendon that occurs when the forces placed upon the tendon exceed its tensile strength)
- ◻ Ligamentous rupture (tearing of the bands of fibrous tissue connecting bones or cartilages, serving to support and strengthen joints)
- ◻ Sprain (wrenching or twisting of a joint, with partial rupture of its ligaments, accompanied by severe pain, impaired function, swelling, heat and discoloration of the skin)
- ◻ Lesion of meniscus or cartilage (injuries of meniscus (knee) or joint surfaces)
- ◻ Strain/muscle rupture/tear
- ◻ Contusion/haematoma/bruise
- ◻ Tendinosis/tendinopathy (all non-inflammatory and inflammatory conditions affecting a tendon, "tendinitis")

- ◻ Arthritis/synovitis/bursitis (inflammation of any part of a joint or structures near the joint, characterized by pain on movement, tenderness, heat and swelling)
- ◻ Fasciitis/aponeurosis injury (inflammation or injury of a sheet like tendinous expansion, e.g. plantar fasciitis)
- ◻ Impingement (compression of a nerve, blood vessel, tendon, ligament or muscle through a constricted space, e.g. sciatica)
- ◻ Laceration/abrasion/skin lesion
- ◻ Dental injury/broken tooth
- ◻ Nerve injury/spinal cord injury
- ◻ Muscle cramps or spasm
- ◻ Other
- ◻ Don´t know

Comments: Great options given. You've covered all the bases in my opinion

Question 21
Who made the diagnosis?

- ◻ Doctor
- ◻ Physical therapist
- ◻ Other health professional
- ◻ Coach
- ◻ Made the diagnosis myself

Comments: Good

Question 22
Have you had this type of injury before?

- ◻ No, this is a new injury
- ◻ Yes, this is an ongoing injury
- ◻ Yes, this is a worsening of an ongoing injury
- ◻ Yes, this is recurrence of a previous, fully recovered injury

Comments: Good

Question 23
How long since the last time you were injured? (months)

Comments: **Good**

Question 24
Injury onset

□ Gradual onset
□ Sudden onset

Comments: **Good**

Question 25
Was the injury caused by contact? (Collision, fall etc.)

□ Yes
□ No

Comments: **Good**

Question 26
Under what circumstances?
□ Training
□ Competition

Comments: **Include an option of other – injury could be work related or socially related too – with an option to describe**

Question 27
What kind of training?

□ Training in primary sport (swim, cycle, or run)
□ Alternative training

Comments: **Good. You could break this down into primary sport, core and balance, flexibility, strength and other, if you would like.**

Question 28
Type of alternative training?

Comments: See comment in question 27

Question 29
Describe the injury onset as briefly and precisely as possible (situation/mechanism)

Comments: I would suggest providing an example of the description.

Question 30
Did you seek medical attention?

- □ No
- □ Doctor
- □ Physiotherapist
- □ Other

Comments: Good

Question 31
What kind of other medical attention?

Comments: Good

Question 32
Have you experienced any other illnesses, injuries or other health problems during the past 7 days?

□ Yes

□ No

Comments: Good

APPENDIX IX: VALIDATION DOCUMENT FROM EXPERT 2

Section A: Health Problems

Please answer all questions regardless of whether or not you have experienced health problems in the past week. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.

If you have several illness or injury problems, please refer to the one that has been your worst problem this week. You will have a chance to register other problems at the end of the questionnaire.

Question 1
Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the past week?

□ Full participation without health problems
□ Full participation, but with injury/illness
□ Reduced participation due to injury/illness
□ Cannot participate due to injury/illness

Comments:
Just a general comment – with any questionnaire, think about the end-game. Think about the type of data you want at the end of your data collection. And then ask yourself whether these questions will give you the appropriate data that you can analyse to answer your research questions. That's important. Often, at the end of your data collection when you sit down to analyse it, you realize that you do not have the necessary data to actually answer your research questions to meet your study's objectives. So try and pilot a scenario where you have the data that these questionnaires would yield and then see whether the data obtained would suffice in answering your research questions.

Or at the least, make sure you have thought in depth about what data you want to have at the end of your participants completing these questionnaires.

Question 2
To what extent have you reduced you training volume due to injury, illness or other health problems during the past week?

□ No reduction
□ To a minor extent
□ To a moderate extent
□ To a major extent

☐ Cannot participate at all

Comments:

Question 3

To what extent has injury, illness or other health problems affected your training performance during the past week?

☐ No effect
☐ To a minor extent
☐ To a moderate extent
☐ To a major extent
☐ Cannot participate at all

Comments:
Above you refer to volume as training volume – for consistency be specific about what performance details are required. Training performance? Or competition performance if participating in events?

Question 4

To what extent have you experienced symptoms/health complaints during the past week?

☐ No symptoms/health complaints
☐ To a mild extent
☐ To a moderate extent
☐ To a severe extent

Comments:

Question 5

Is the health problem referred to in the questions above an injury or an illness?

☐ Injury
☐ Illness
☐ I have not had an injury/illness

Comments:
Just a thought – you might want to include a simple definition for each – this will ensure clarity and consistency when the participants are answering. For example – someone might not list allergy related mild sinusitis as an illness, whereas another participant might. However, if you define illness (the operational definition of illness in your study) you will get more consistent data pertaining to illness. Also some participants might not classify a "mild niggle" as an injury, whereas others might. Once again – definitions will give clarity and ensure that you get reliable data.

Question 6 - Injury Area

Please select box that best describes the location of your injury. If the injury involves several locations please now select the main area. You will have a chance to record other injuries at the end of the questionnaire.

- ☐ Head/face
- ☐ Neck
- ☐ Shoulder (including clavicle)
- ☐ Upper arm
- ☐ Elbow
- ☐ Forearm
- ☐ Wrist
- ☐ Hand/fingers
- ☐ Chest/ribs
- ☐ Abdomen
- ☐ Thoracic spine/upper back
- ☐ Lumbar spine/lower back
- ☐ Pelvis and buttock
- ☐ Hip and groin
- ☐ Thigh
- ☐ Knee
- ☐ Lower leg
- ☐ Ankle
- ☐ Foot/toes
- ☐ Other

<u>**Comments:**</u>
How do the participants know whether the different regions pertain to the same injury? This could potentially be confusing for participants.
Also, what if they have multiple injuries? Which one should they list here? The most severe one? I know it says they will have a chance to record other injuries at the end, but which one should they put in this section? Maybe clarify that.

Question 7 - Illness Symptoms

Please check the boxes corresponding to the major symptoms you have experienced during the past week. You may select several alternatives.

- ☐ Fever
- ☐ Fatigue/malaise
- ☐ Swollen glands
- ☐ Sore throat
- ☐ Blocked nose/running nose/sneezing
- ☐ Cough
- ☐ Breathing difficulty/tightness
- ☐ Headache

☐ Nausea
☐ Vomiting
☐ Diarrhoea
☐ Constipation
☐ Fainting
☐ Rash/itchiness
☐ Irregular pulse/arrhythmia
☐ Chest pain/angina
☐ Abdominal pain
☐ Other pain
☐ Numbness/pins and needles
☐ Anxiety
☐ Depression/sadness
☐ Irritability
☐ Eye symptoms
☐ Ear symptoms
☐ Symptoms from urinary tract/genitalia
☐ Other. Please specify ______________________________________

Comments:
What constitutes a major symptom?

Question 8

Have you lost one or more days of training/competition during the past week due to injury, illness or other health problems?

☐ No
☐ 1-3 days
☐ 4-7 days
☐ 8-28 days
☐ >28 days

Comments:
Your question asks about "days missed per WEEK" – but your answer options have options that include a period longer than a week. So I'm assuming your question should be per MONTH?

Section B: Training

Question 9

Please report your total number of training hours for the past week. Include all forms of training together (swim, bike, run, strength/core/balance/other).

Comments:

If you are wanting to assess the influence of training parameters on injury incidence/prevalence in this population then I think hours could potentially limit your statistical analyses – you will end up with a very small standard deviation which means that you would have to have a very large sample size to pick up effect sizes or correlations between training volume and injury incidences. In my opinion, a better operational definition for training volume in your study would be mileage completed. You can always have both. But I definitely think that having a mileage for the swimming, cycling and running respectively will improve the ease of your data analyses.

Secondly, you have included volume and intensity – which are only two of the main training parameters. But in this section I think frequency of training could be potentially important. A lot of triathletes have numerous training sessions per day – I think the number/frequency of training sessions per week could be a valuable but of information – as with an increased frequency, there would be reduced recovery time for the tissue and would be expected to be a significant risk factor for injury development. Adding a frequency parameter to the questionnaire will therefore enhance your ability to analyse the effects of all the training parameters on injury/illness development and therefore provide you with stronger data and a more in-depth answer to your research question.

Response:

Thank you for this suggestion. Although I see that using mileage may be useful, and has been stated in the literature as one of the many option to measure external training load (Gabbet, 2016), previous research on Iron-distance athletes has not used this operational definition (Andersen, 2013, Zwingenberger et al, 2014). Previous research uses hours for training volume calculations, and I think it will thus perhaps be difficult to make comparisons to previous research in terms of how training load impacts on injury and illness if I change this to mileage. The workload calculation is RPE x volume, so yes I can calculate it using mileage instead, however this will deviate from previous research methods. Another limitation I fear from using mileage is that there may be a bias in terms of inclusion towards athletes using monitoring devices for distance, as not all participants may have such devices. Hours of training is a simple way that does not exclude participation in the study.

Question 10

How many hours did you swim during the past week?

Comments:

Question 11
Please report your average rating of perceived exertion for your swim training during the past week.

6
7 very, very light
8
9 very light
10
11 fairly light
12
13 somewhat hard
14
15 hard
16
17 very hard
18
19 very, very hard
20

Comments:

Question 12
How many hours did you cycle during the past week?

Comments:

Question 13
Please report your average rating of perceived for your bike training during the past week.

6
7 very, very light

8
9 very light
10
11 fairly light
12
13 somewhat hard
14
15 hard
16
17 very hard
18
19 very, very hard
20

Comments:

Question 14

How many hours did you run during the past week?

Comments:

Question 15

Please report your average rating of perceived exertion) for your run training during the past week.

6
7 very, very light
8
9 very light
10
11 fairly light
12
13 somewhat hard
14
15 hard
16
17 very hard
18
19 very, very hard

20

Comments:

Question 16

How many hours did you do core/strength/balance/other exercise during the past week?

Comments:

Maybe try and refine this section on alternative training – strength is very broad. It could indicate upper limb strengthening which clearly wouldn't change the risk of lower limb injury. And vice versa. So maybe try and tighten this up a bit to assist with your data analyses – maybe have a list of specifics that the participants can tick so that you can analyse your data in categories. Just an idea. Potentially:

- Core strengthening
- Plyometric lower limb training
- Plyometric upper limb training
- Body weight or resistance lower limb strengthening
- Body weight or resistance upper limb strengthening
- Other modes of cardiovascular training: elliptical; rowing; arm cycle ergometer

Other functional training activities: squash; surfing; etc.

Question 17

Please report your average rating of perceived exertion (for your core/strength/balance/other exercise training during the past week.

6
7 very, very light
8
9 very light
10
11 fairly light
12
13 somewhat hard
14
15 hard
16
17 very hard
18
19 very, very hard
20

Comments:

Question 18

How many hours of racing have you completed during the past week?

Comments:

This one "competition" question seems a bit random here. If you want competition data, you need to be comprehensive.

Number of race events during the past week (frequency); mileage (and hours if you want) covered during race events during the past week (volume); Time taken to complete race events in the past week (intensity).

Response:

Thank you for the suggestion. Again though, similar to the previous suggestion, I think using hours is more feasible. I will add more details to the competition question though, such as an RPE value for intensity. In terms of number of events (frequency), I think the total volume for the week is feasible to assess impact on injury and illness. Even if they do two races in the week for example, the total competition workload (hours x RPE) for the week should be sufficient to identify any relationships between load and injury/illness.

Section C: Acute injuries

Please report whether you have had injuries or other health problems causing reduced training or racing during the past week. Please answer "yes" to this question even if you have already given us information on the injury through previous questions in this survey.

Question 19

Illness/Injuries

◻ Yes, I have been injured
◻ No, I have trained 100%

Comments:

The purpose with this question is to clarify what type of injury you have. Please try to classify the injury type, even if you have not seen a doctor to obtain a specific diagnosis.

Question 20

Injury type

◻ Concussion (symptoms like disorientation, dizziness, loss of memory, nausea or vomiting due to a blow to the head)
◻ Fracture (traumatic) (broken bone caused by sudden impact)
◻ Stress fracture (overuse) (fracture in a weight bearing bone caused by repetitive stress (e.g. running), a stress fracture in one of the small bones in the foot will typically cause severe pain at the beginning of a run, moderate pain during the run and severe pain at the end and after the run)
◻ Other bone injuries
◻ Dislocation, subluxation (the total or partial displacement or misalignment of bones in a joint, most often caused by a sudden impact to the joint)
◻ Tendon rupture (tearing of a tendon that occurs when the forces placed upon the tendon exceed its tensile strength)
◻ Ligamentous rupture (tearing of the bands of fibrous tissue connecting bones or cartilages, serving to support and strengthen joints)
◻ Sprain (wrenching or twisting of a joint, with partial rupture of its ligaments, accompanied by severe pain, impaired function, swelling, heat and discoloration of the skin)
◻ Lesion of meniscus or cartilage (injuries of meniscus (knee) or joint surfaces)
◻ Strain/muscle rupture/tear
◻ Contusion/haematoma/bruise
◻ Tendinosis/tendinopathy (all non-inflammatory and inflammatory conditions affecting a tendon, "tendinitis")

- ☐ Arthritis/synovitis/bursitis (inflammation of any part of a joint or structures near the joint, characterized by pain on movement, tenderness, heat and swelling)
- ☐ Fasciitis/aponeurosis injury (inflammation or injury of a sheet like tendinous expansion, e.g. plantar fasciitis)
- ☐ Impingement (compression of a nerve, blood vessel, tendon, ligament or muscle through a constricted space, e.g. sciatica)
- ☐ Laceration/abrasion/skin lesion
- ☐ Dental injury/broken tooth
- ☐ Nerve injury/spinal cord injury
- ☐ Muscle cramps or spasm
- ☐ Other
- ☐ Don´t know

Comments:
This will cause problems in the internal validity of the study – self reported injury is not an accurate report. You either need to include in your definition of acute injury that it has been diagnosed by a medical practitioner – or use area to classify and report prevalence of area of injury rather than specific injury. Because if a lot of your questionnaires come back with self-report diagnoses then the validity of your findings will be severely affected.

Response:
Thank you for commenting extensively on this. Although I agree the internal validity will be affected, self-reporting of injuries has been done in previous research when reporting injuries (Andersen, 2013). The development of the OSTRC Questionnaire was done via self-reported measurements (Clarsen, 2013). In their analysis of the results from the study, they mentioned that a potential limitation was the use of self-reported measures, and that a medical diagnosis would be preferred, however, they did state also that this creates a logistical and financial limitation. I think in this study, it would be wrong to assume that participants will always follow-up at a doctor/physio for a diagnosis, especially regarding overuse injuries, as stated by by Clarsen et al (2013). These specific injuries have been used in the consensus statement by Fuller et la (2006) in the development of a validated injury reporting questionnaire, and I think it would be feasible to use these classifications.

Comments:
Section C is “Acute Injury” – these are overuse injuries??

Response:
Thank you for the comment. I agree with you. I have thought about this thoroughly, and I think that these options are here (from the original questionnaire by Fuller et al 2006) in order to classify the injury for data analysis, whether acute overuse. Perhaps the heading ‘Acute Injuries’ is misleading, and I have changed it to ‘Injury Classification’, perhaps that makes it a bit more clear?.

Question 21
Who made the diagnosis?

- ☐ Doctor
- ☐ Physical therapist
- ☐ Other health professional
- ☐ Coach

□ Made the diagnosis myself

Comments:

Question 22

Have you had this type of injury before?

□ No, this is a new injury
□ Yes, this is an ongoing injury
□ Yes, this is a worsening of an ongoing injury
□ Yes, this is recurrence of a previous, fully recovered injury

Comments:
Relevance? Perhaps you should consider a baseline questionnaire to establish any injuries at the start before the training period and data collection. This will also help establish your injury status of the study sample before the start – therefore allowing you to identify incidences of injury over the period or the prevalence of the injury at times during the period. **Response**: Thank you for the comment. I have already included in the demographical information sheet that each participant will fill in a space to record past injuries. This question here is to assist in classifying the injury as a new or repeated injury, as outlined by Fuller et al (2006).

Question 23

How long since the last time you were injured? (months)

Comments:
From question 23 downwards – what will these add to your data collection? I am not too sure what these are in aid of. Is it trying to establish the nature of the injury? I think this last section needs to be tightened up – try and think what information you need to analyse your data for your research questions.

Response:
Thanks for the comment. These questions are to establish more information regarding the nature of the injury. i.e. repetitive injuries, acute or overuse, mechanism, etc. This is following the reporting methods outlined in the consensus statement on reporting of acute injuries by Fuller et al (2006), where a full detailed report of the injury can be obtained and used for classification. I think it is better to stick to the questions as best as possible from previous research as it will improve the comparison of data between studies.

Comments:
From question 23 downwards – what will these add to your data collection? I am not too sure what these are in aid of. Is it trying to establish the nature of the injury? I think this last section needs to be tightened up – try and think what information you need to analyse your data for your research questions. Try and clarify this – I'm assuming you are talking about the injury previous to the current one? But participants could get confused.

Response:
Thank you. This question is a follow-up to the last option of the previous question where details regarding the previous injury will be obtained. The online questionnaire uses skip logic to answer these if necessary.

Question 24
Injury onset

□ Gradual onset
□ Sudden onset

Comments:
Is this in relation to the current injury or the last injury asked about in the question above? Confusing.

Question 25
Was the injury caused by contact? (Collision, fall etc.)

□ Yes
□ No

Comments:
What about non-contact acute mechanisms – i.e. a roll or twist? I'm assuming you are trying to establish whether it was an acute injury or overuse here? But there are more acute mechanisms than direct trauma.

Question 26
Under what circumstances?
□ Training
□ Competition

Comments:

Question 27
What kind of training?

□ Training in primary sport (swim, cycle, or run)
□ Alternative training

Comments:

Question 28
Type of alternative training?

Comments:

Question 29
Describe the injury onset as briefly and precisely as possible (situation/mechanism)

Comments:

Question 30
Did you seek medical attention?

□ No
□ Doctor
□ Physiotherapist
□ Other

Comments:

Question 31
What kind of other medical attention?

<u>Comments:</u>

Question 32
Have you experienced any other illnesses, injuries or other health problems during the past 7 days?

- ☐ Yes
- ☐ No

<u>Comments:</u>

APPENDIX X: FEASABILITY STUDY DOCUMENT

<u>IRONMAN QUESTIONNAIRE FEEDBACK</u>

1. Do you feel that there any questions that do not make sense to you, or that you don't completely understand? *Please state which question number and why it is confusing*.

2. Do you feel that there are any explanations of terms or questions that are difficult to understand, or may be described poorly? *Please state which question number and why it is confusing*.

3. How long did the questionnaire take complete?

4. Did you find the structure and logic of the questionnaire easy to complete?

5. Any further suggestions to make the questionnaire easier to complete?

APPENDIX XI: PARTICIPANT DEBRIEFING DOCUMENT

UNIVERSITY OF CAPE TOWN
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14/12/201

Dear participant,

I would like to thank you for your participation in this research study on training load, injury, and illness in iron distance triathletes. Your input has assisted the preparation of a scientific research paper as part of a master's degree in sports and exercise physiotherapy. It has been a long process of data analysis and carefully writing up the final results from the study. I am pleased to inform you that the process is complete, and I hope you will find the results interesting and useful.

There were some minor challenges along the way. The biggest of these were the small sample size used in this study. A larger pool of participants would have made the results of the study a lot more relevant to the greater triathlon community. Another challenge we met was the lack of current research in this specific area of endurance sports. There is not much research regarding iron distance triathletes, and so it was difficult to compare the results of this study to other studies. These challenges do not take away from the results and success of this study.

We hope that there will be a growing body of knowledge in the field of iron distance triathlon. It is a sport growing in popularity amongst the amateur sports population, and it is the responsibility of sports practitioners across the board to make aware the potential risk associated with participation in the sport. Please read through the following results document and infographic regarding the specific study results, and if you have any questions please don't hesitate to contact me.

Kind regards

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Dear participant,

Thank you for your participation in this study on training load, injury, and illness in iron distance triathlon. Your feedback to the weekly surveys was hugely beneficial to the results of this study. Your individual results from the study are shown in the tables below:

Amount of injuries and illness:

Participant number	Number of new injuries	Number recurring injuries	Number of illness

Training loads:

Average weekly training hours	Average weekly swim hours	Average weekly bike hours	Average weekly run hours	Average weekly training intensity (RPE)	Average weekly training load	Average weekly acute:chronic training load

The training load value was calculated using the average training volume and average training intensity (RPE). This has been shown to be a good way of monitoring training load in athletes. Acute:chronic training load gives an indication of the acute training load in one week compared to the three week cumulative chronic training load before that week. Normal values for acute:chronic training loads in endurance sports have not yet been published, but in team sports a “safe zone” for reduced risk for injury and illness is 0.8-1.3.

THE IMPACT OF TRAINING LOAD ON INJURY AND ILLNES IN A 12-WEEK PREPARATION FOR AN IRON-DISTANCE TRIATHLON

STUDY RESULTS AND SUMMARY

STUDY POPULATION

37 amateur triathletes (22 ♂ & 15 ♀)
Average age = 35 years
Average event finishing time = 13 hours
Average weekly training:
- volume (hours) = 10.5 hours
- intensity (RPE) = 13
- load (arbitrary units) = 8170

INJURY AND ILLNESS RESULTS

High prevalence (total burden of injury/illness over 12 weeks of training) and incidence (number of new injury/illness).

INJURY

high burden of new injury (65% of participants, 9 injuries /1000 training hrs)
high burden of overuse injury (88% of injuries, 8 injuries /1000 training hrs)
low burden of acute injury (11% of participants, 1 injury /1000 training hrs)
knee was the most common area of injury
on a severity scale of 0-100, overuse injuries averaged 36 (mild)

ILLNESS

high burden of new illness (62% of participants)
most common symptoms were fatigue/malaise
on a severity scale of 0-100, illness averaged 51 (moderate)

TRAINING LOAD, INJURY, & ILLNESS

Low, moderate, and high training loads did not show any significant realtionship to injury or illness. Here are some evidence based methods to use during training for a triathlon. [ref: Gabbett (2016)]

✓ Gradual increases in chronic training load

✓ Avoid heavy weekly spikes in acute training load

✓ A two week high training load followed by a week of lower training load can be used to avoid high three week chronic training loads

✓ Monitor training load using internal (heart rate, RPE, etc.) and external (hours, power, speed, etc.) training load measures

APPENDIX XII: ODDS RATIO CALCULATIONS ACCORDING TO EARLY, MIDDLE, AND LATE PHASES

TRAINING LOAD AND INJURY

EARLY PHASE

Training load component	Subgroup	Odds ratio (95% CI)
Acute:chronic workload (ratio)	≥ 0.60 (Reference)	1.00
	0.40 to 0.59	1.43 (0.01-3.31)
	0.20 to 0.39	1.43 (0.01-3.31)
	≤ 0.19	Infinity
Acute training load (AU)	≥ 16000 (Reference)	1.00
	12000-15999	0.5 (0.04-6.68)
	8000-11999	0.17 (0.01-3.12)
	≤ 8000	0.96 (0.09-9.83)

MID PHASE

Training load component	Subgroup	Odds ratio (95% CI)
Acute:chronic workload (ratio)	≥ 0.60 (Reference)	1.00
	0.40 to 0.59	0.13 (0.01-2.58)
	0.20 to 0.39	0.28 (0.03-2.94)
	≤ 0.19	0
Acute training load (AU)	≥ 16000 (Reference)	1.00
	12000-15999	infinity
	8000-11999	infinity
	≤ 8000	infinity

LATE PHASE

Training load component	Subgroup	Odds ratio (95% CI)
Acute:chronic workload (ratio)	≥ 0.60 (Reference)	1.00
	0.40 to 0.59	infinity
	0.20 to 0.39	infinity
	≤ 0.19	infinity
Acute training load (AU)	≥ 16000 (Reference)	1.00
	12000-15999	infinity
	8000-11999	infinity
	≤ 8000	infinity

TRAINING LOAD AND ILLNESS

EARLY PHASE

Training load component	Subgroup	Odds ratio (95% CI)
Acute:chronic workload (ratio)	≥ 0.60 (Reference)	1.00
	0.40 to 0.59	infinity
	0.20 to 0.39	infinity
	≤ 0.19	infinity
Acute training load (AU)	≥ 16000 (Reference)	1.00
	12000-15999	infinity
	8000-11999	infinity
	≤ 8000	infinity

MID PHASE

Training load component	Subgroup	Odds ratio (95% CI)
Acute:chronic workload (ratio)	≥ 0.60 (Reference)	1.00
	0.40 to 0.59	0.13 (0.01-2.58)
	0.20 to 0.39	0.39 (0.04-3.88)
	≤ 0.19	1.33 (0.06-31.12)
Acute training load (AU)	≥ 16000 (Reference)	1.00
	12000-15999	infinity
	8000-11999	infinity
	≤ 8000	infinity

LATE PHASE

Training load component	Subgroup	Odds ratio (95% CI)
Acute:chronic workload (ratio)	≥ 0.60 (Reference)	1.00
	0.40 to 0.59	infinity
	0.20 to 0.39	infinity
	≤ 0.19	infinity
Acute training load (AU)	≥ 16000 (Reference)	1.00
	12000-15999	0.38 (0.02-6.00)
	8000-11999	0.5 (0.04-5.64)
	≤ 8000	1.2 (0.13-11.08)