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THE EPIDEMIOLOGY OF NON-TRAUMATIC INJURIES IN ROAD CYCLISTS PARTICIPATING IN THE CAPE TOWN CYCLE TOUR

By

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Master of Science (Biokinetics)

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In the

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Declaration

I, the undersigned, declare that the dissertation hereby submitted to the University of Pretoria for the degree MSc (Biokinetics) and the work contained therein is my own original work and has not previously, in its entirety or in part, been submitted to any university for a degree.

Signed 

Dedication

I dedicate this study to my wife, Cecile, and our children Johann and Alto.

Through your selfless sacrifices, you ensured that I always had the opportunity to go after my dreams, and this was one of them. I am amazed at the amount of love and support you have given me, not only throughout this journey, but always. I cannot thank you enough!

I love and appreciate you.

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Synopsis

Title	The epidemiology of non-traumatic injuries in road cyclists participating in the Cape Town Cycle Tour.
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Degree	MSc (Biokinetics)

Cycling is a popular form of transportation, recreation, fitness and sporting activity worldwide and South Africa. There are over 450 annual cycling events in South Africa and approximately 600 000 cyclists participate in at least one of these events annually. In spite of the popularity of road cycling, literature is rather scarce on the epidemiology of non-traumatic injury in cyclists.

The study aimed to describe the epidemiology, clinical characteristics and severity of non-traumatic cycling injuries (NTCIs), and determine the independent risk factors associated with NTCIs in recreational cyclists that registered for the Cape Town Cycle Tour (CTCT).

All cycle race entrants from the 2016 CTCT were required to complete an online medical screening questionnaire, at the time of registration, developed to provide clinical information for medical staff on race day. The screening questions considered: cycling training / racing history, medical history and general medication use for chronic disease and medication use before and during racing.

A total of 35914 cyclists entered the 2016 CTCT, and 27349 completed the questionnaire with 21902 providing written informed consent for their data to be used. The final study population was 21824 (60.8% of all cycle race entrants) as 78 cyclists had missing / incomplete data. NTCIs were reported by 617 cyclists and 29 cyclists reported more than one NTCI. The epidemiology of NTCIs is reported for the 617 cyclists with NTCI, while the clinical characteristics and severity of NTCIs is reported for the 646 NTCIs.

NTCIs, and their risk factors in recreational cyclists have not been well studied. This study shows that 1 in 40 recreational cyclists report ever suffering from a NTCI that was severe enough to interfere with cycling, require treatment or seek medical advice from a health professional. These NTCIs affect mostly the knee, lower back and shoulder and more than 37% of the injuries were severe enough to affect training and competition. The multi-variate analysis of the independent risk factors associated with NTCIs shows novel findings, namely: an association between NTCIs and cycling training/racing history [increased years of participation in distance cycling events >2 hours, and increased average weekly training / racing frequency in the last 12 months (times per week)], a history of chronic disease [any symptoms of CVD, any respiratory disease, any GIT disease, and any nervous system / psychiatric disease], and a history of medication use [any regular prescribed medication use for chronic disease, and any analgesic / anti-inflammatory medication (AAIM) used in the week before or during racing].

Of importance is that clinicians should consider NTCIs are not associated with a single aetiology, but rather a more complex interaction of a variety of intrinsic and extrinsic factors requiring careful and systematic clinical assessment. Clinicians should explore the possibility that NTCIs may be associated with underlying chronic disease and / or side effects of medications that are used by cyclists. Although data is self-reported and a potential for recall bias exists, the large sample size mitigates these study limitations. Future research should determine the cause-effect relationship between NTCIs and the factors identified in this research, and explore possible pathophysiological mechanisms that may link NTCIs to underlying chronic disease and medication use.

Key words: cycling, injuries, non-traumatic injuries, non-traumatic cycling injuries overuse injuries, chronic injuries, risk factors, epidemiology, severity of injuries, SAFER study

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List of Abbreviations

AAIM	Analgesic / Anti-inflammatory medication
ACL	Anterior cruciate ligament
AKP	Anterior knee pain
BMX	Bicycle motocross
CTCT	Cape Town Cycle Tour
CVD	Cardiovascular disease
ED	Emergency Departments
GIT	Gastrointestinal tract
ITB	Iliotibial band
ITBFS	Iliotibial band friction syndrome
ITU	International triathlon union
km	kilometres
km/h	kilometres per hour
LBP	Lower back pain
MTB	Mountain bike
NCDs	Non-communicable diseases
NSAIDs	Nonsteroidal anti-inflammatory medication
NTCIs	Non-traumatic cycling injuries
NTCI	Non-traumatic cycling injury
PFPS	Patellofemoral pain syndrome
PR	Prevalence ratio
Q-angle	Quadriceps angle

CHAPTER 1: INTRODUCTION

1.1. INTRODUCTION AND MOTIVATION FOR THE STUDY

It is well-established that regular participation in physical activity has numerous health benefits, including the prevention and management of chronic non-communicable disease.[1-3] The substantial growth in the popularity to participate in community based endurance sports events is also evident in the South African context. Events such as the Cape Town Cycle Tour (CTCT), multi-stage running and mountain bicycle races (Cape Epic, Augrabies Extreme Marathon, Wine to Whales), distance running events (Comrades marathon, Two Oceans marathon, Cape Town Marathon,) and many other long distance running events, swimming, triathlons (Iron Man, ITU World Triathlon series), canoeing and walking events (e.g. Big Walk and Blisters for Bread) are increasing in popularity with continuous growth in number of participants. These events, which are usually held annually in a number of locations in South Africa, attract large numbers of elite and recreational athletes with varying ability.

Cycling is also a popular form of transportation, recreation, fitness and sporting activity amongst people of all ages who ride on road and off road, using a variety of bicycle types including mountain bikes (MTB), touring bicycles, racing bicycles, stunt (BMX) bicycles and stationary exercise bicycles.[4-18] There are over 450 cycling events held in South Africa annually and approximately 600 000 active cyclists in South Africa participate in at least one of these event per year.[19] Competitive cycling includes the disciplines of road racing, time trial, cyclocross, mountain biking, track, BMX, and triathlon.[9] Road cycling covers a broad spectrum of events from multi-stage races to one-day races, involving both professional and amateur cyclists of varied characteristics. From this cycling characteristic alone, it would be assumed that the spectrum of resultant injuries is extensive too.

Possibly the most well renowned multi-stage cycling event is the Tour de France (21 stages, 3516 km), whilst the Dubai Tour (5 stages, 802 km), the Herald Sun Tour (4 stages, 630.6 km), Giro d'Italia (21 stages, 3572.2 km), La Vuelta (21 stages, 3297.7 km), and the ABSA Cape Epic (7 stages, 691 km) are also noted as prominent international multi-stage cycling events.

Prominent international one-day races, open to professional cyclist only, include the Milan–San Remo (296 km), Tour of Flanders (260 km), Paris–Roubaix (172 km), Liège–Bastogne–Liège (253 km), Giro di Lombardia (245 km). South Africa has two prominent one day cycling events open to both professional and amateur cyclists, namely the 94.7 Cycle Challenge (94 km, attracting over 30 000 cyclists in 2016) and the CTCT (109 km, attracting over 34 000 cyclists in 2016).

Due to the increased popularity of cycling there is an increase in the number of injuries amongst both amateur and professional cyclists.[4-5,7-10,14,17-18,20] NTCIs are thought to be the predominant injury type in sports that involve long, repetitive training sessions (cycling, swimming and long-distance running).[21] Little is known about the true extent and severity of NTCIs in sports and in one day cycling events, largely because of the methodological challenges involved in the recording of the NTCIs.[22] The most common non-traumatic injury sites reported in road cycling are the knee and ankle, back, neck and shoulders, hands, wrists, buttocks and perineum.[9,11,15,18,23-33]

NTCIs constitute a significant diagnostic and therapeutic problem because the symptoms are often diffuse and non-specific, but a proper diagnosis followed by adequate treatment can improve or eliminate most of these conditions.[34] It is very important to have a proper understanding of NTCIs as this is key to assist athletes, trainers, and coaches in preventing NTCIs.[34]

In spite of the popularity of road cycling, literature is rather scarce on the epidemiology of non-traumatic injury in cyclists.[11] The literature on the epidemiology of non-traumatic injury is somewhat more abundant in mountain biking and triathlon modalities.[11] In road cycling, there are limited epidemiological studies on NTCIs,[5] but most of these studies refer to leisure or transportation activities, and only a few epidemiological studies have been published on amateur and professional road cyclists engaged in training and competitions.[5] Most studies on NTCIs are in professional cyclists that attend training camps or during cycle tours ≥5 days[15,25-26,29] and little is known about NTCIs in mass-participation in one day cycling events that attract recreational cyclists.[24,29] The understanding of the non-traumatic injury profile and the identification of possible risk factors associated with these injuries in recreational cyclists' events is needed in order to develop appropriate prevention strategies.

1.2. RESEARCH QUESTION

For this study, the following research question was formulated:

"What are the epidemiology of injuries, and independent risk factors associated with non-traumatic cycling injuries occurring in road cyclist entered in the 2016 Cape Town Cycle Tour?"

1.3. AIM OF THE STUDY

The aim of this study was to describe the epidemiology, clinical characteristics and severity of NTCIs, and determine the independent risk factors associated with NTCIs in recreational cyclists that registered for the 2016 CTCT.

1.4. OBJECTIVE OF THE STUDY

The specific objectives were to:

- Describe the epidemiology of NTCIs with regards to the:
  - lifetime prevalence, retrospective annual incidence and point prevalence,
  - clinical characteristics (main anatomical region and specific anatomical sites affected, prevalence of specific common NTCIs, and NTCIs by tissue type affected),
  - severity (duration of symptoms, and severity grade) of NTCIs,
- Explore the following specific risk factors associated with NTCIs using a multi variable analysis:
  - cyclist demographics (age group and gender),
  - cycling training / racing history,
  - a history of existing chronic disease, and
  - medication use.

1.5. RESEARCH APPROACH

A quantitative research approach was used. The quantitative research approach focusses on what can be measured and involves collecting and analysing objective

(often numerical) data that can be organised into statistics.[35] In this study, data was collected from cyclists who registered to participate in the 2016 CTCT.

1.6. RESEARCH DESIGN

A cross-sectional prevalence survey design was used. A cross-sectional prevalence survey design is defined as a design that collects data from a variety of subjects at a given point in time which examines the relationships of injury prevalence with other factors at one point in time in a defined population.[35] Data collected using a cross-sectional survey on road cyclists participating in the 2016 CTCT was used for the purpose of this study.

1.7. RESEARCH PROCEDURE AND STRATEGY

The flow diagram depicted as Figure 1.1 outlines the procedures that were followed throughout the study.

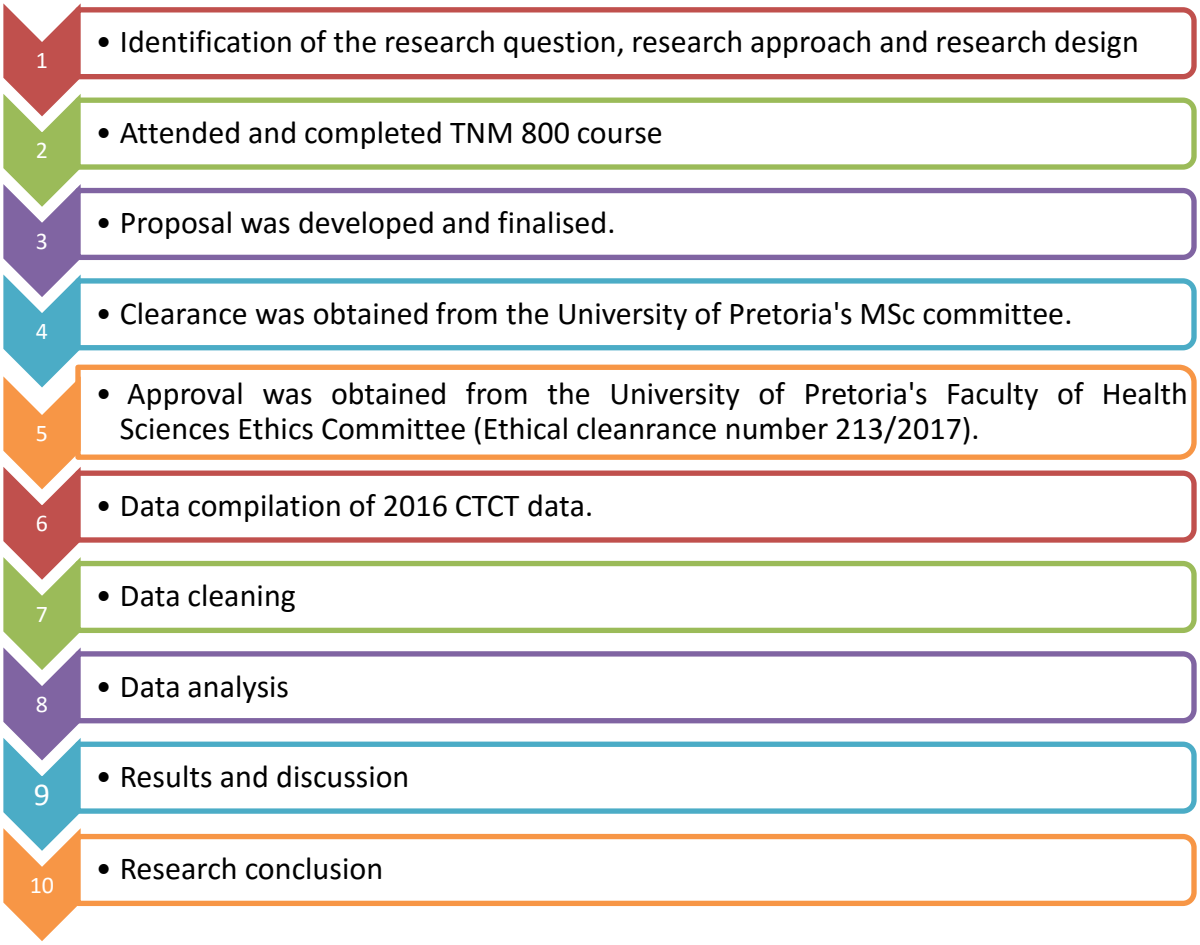

Figure 1.1: Flow diagram of the research process followed

1.8. FLOW OF DISSERTATION

Chapter 2 presents the literature review. Paper 1 is presented in Chapter 3 and describes the epidemiology, clinical characteristics and severity of NTCIs in recreational cyclists. The methodology utilised in conducting this study, the statistical analysis used, and the discussion of the results in relation to the existing literature is detailed in Paper 1. Paper 2 is presented in Chapter 4, and explores independent risk factors associated with NTCIs in recreational cyclists. The methodology utilised in conducting this study, the statistical analysis used, and the discussion of the results in relation to the existing literature is detailed in Paper 2. Chapter 5 concludes the study, documents its practical application and highlights recommendations regarding future research.

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CHAPTER 2: LITERATURE REVIEW

2.1. CYCLING

2.1.1. Popularity of Cycling

Cycling is a popular form of transportation, recreation, fitness and sporting activity amongst people of all ages who ride on road and off road, using a variety of bicycle types including MTB, touring bicycles, racing bicycles, stunt (BMX) bicycles and stationary exercise bicycles.[1-15] The basic components of a bicycle are maintained across all designs. These components include the frame, seat post, saddle, handlebar, crank arm, and pedals.[15] Data on the production of bicycles show that there are approximately 150 million bicycles in Europe, 100 million in United States and 500 million in China.[2] In North America, both road and mountain bicycling are increasing in popularity, with the Canadian biking rates exceeding those of the United States.[1] According to the American Bureau of Transportation Statistics, it is estimated that more than 49 million Americans ride bicycles at least monthly, with over 5 million people riding at least 20 days per month.[10] In the Netherlands, there are 29 000 km of cycle tracks and 27% of all trips taken in Holland are done by bicycle.[16] In 2013, approximately 8.5 million Americans participated in mountain biking, up by 20% from 2007 with more than 2.7 billion MTB outings per year.[5] Cycling is considered to be one of the fastest-growing sports in South Africa, with approximately 500 000 bicycles sold in 2008.[17] There are over 450 cycling events in South Africa per year and approximately 600 000 active cyclists participate in at least one of these South African events per year.[18]

2.1.2. Types of Cycling

Competitive cycling includes the disciplines of road racing, time trial, cyclocross, mountain biking, track racing, BMX, and triathlon.[6]

Road racing is the cycle sport discipline held on a paved or tarred roads.[2,9,19-20] Road cycling covers a broad spectrum of events from multi-stage races to one-day races, involving both professional and amateur cyclists of varied experience.

A time trial race is a cycling race where cyclist compete against the clock to complete a given distance in the fastest time possible.[19,21] It can be an individual time trial or a team time trial event.[19,21] The cycling team or individual cyclists sets off at intervals and are required to complete the given distance in the fastest time possible.[19,21] The events usually take place, as with road racing, on paved or tarred roads, or alternatively up a mountain road.[19,21] Time trial cyclists have to generate a sustained power for the duration of their event.[6,21-22]

Cyclocross is a form of bicycle racing that mixes multiple athletic activities, namely riding and running. It consist of many laps of a 1 to 3 km course featuring pavement, wooded trails, grass, sand, dirt, mud, run-ups and sometimes steps.[6,23]

MTB racing is the competitive cycle sport discipline of mountain biking held on off-road terrain including a combination of technical sections, climbs, descents, grass, sand, rock and trails.[5,24-26] MTB is a complex sport involving various types of competitive and recreational challenges.[5,24-26]

During track racing, riders race around in circles on a 42-degree-banked track.[19,27] Olympic-level track racing is comprised of many subcategories, including Individual Pursuit, Points, Sprint races, Kierin, Madison, and Team Pursuit races.[19,27] The speeds at which track racers race and the banked nature of the tracks increase the injury risks for these cyclists.[28]

Bicycle motocross (BMX) is a cycle sport performed on BMX bikes.[19,29-30] BMX racing are held on circuits of around 350 metres. These circuits differ in their configuration and include jumps, banked corners and other obstacles.[19,29-30]

Triathlon is a multidiscipline event involving the completion of three endurance disciplines in successive order, namely - swimming, cycling, and running.[31-32] Official competition in triathlon varies from short distance (Olympic triathlons -1.5 km swim, 40 km cycling, and 10 km running) to long distance (Ironman triathlons - 3.8 km swim, 180 km cycling, and 42.2 km running).[33]

2.1.3. Different types of cycling events

2.1.3.1. International and local multi-stage events

Multi-stage events are characterised by several back-to-back days of racing consisting of mass-start stages and individual and team time trials.[34-36] Possibly the most well renowned multi-stage cycling event is the Tour de France (21 stages, 3516 km), whilst the Dubai Tour (5 stages, 802 km), the Herald Sun Tour (4 stages, 630.6 km), Giro d'Italia (21 stages, 3572.2 km), La Vuelta (21 stages, 3297.7 km), and the ABSA Cape Epic (7 stages, 691 km) are also noted as prominent international multi-stage cycling events. Professional cyclists ride between 25 000km and 30 000km in a season, and complete between 50 to 110 days of intense racing each year.[37-38] The incidence of injuries and illness increases with multi stage events and fatigue becomes a contributing factor to injury and illness.[2]

2.1.3.2. International and local one-day events

A one-day event is characterised by cycling a prescribed distance in a single day.[2,36,39] The typical one-day road race and MTB cycle events may have durations of five hours.[34] Prominent international one-day races, open to professional cyclist only, include the Milan–San Remo (296 km), Tour of Flanders (260 km), Paris–Roubaix (172 km), Liège–Bastogne–Liège (253 km), Giro di Lombardia (245 km). South Africa has two renowned one day cycling events open to both professional and amateur cyclists, namely the 94.7 Cycle Challenge (94 km, attracting over 30 000 cyclists in 2016) and the CTCT (109 km, attracting over 34 000 cyclists in 2016).[40]

Vast differences in cycling exposures between non-competitive and recreational cyclists, and elite professional cyclists exist.[20] An epidemiological study on recreational touring cyclists reported an average annual training volume of 7114km, and an average participation rate of 2.9 in non-competitive events was completed per year.

2.2 CYCLING INJURIES

2.2.1 Introduction

Due to the increased popularity of cycling there is an increase in the total number of injuries amongst both amateur and professional cyclists. The cycling related injuries may cause significant morbidity and mortality.[1-2,4-7,11,14-15,41] Cycling injuries account for around 900 deaths, 23 000 hospital admissions, 580 000 emergency department visits and more than 1.2 million physician visits per year in the United States. These cycling injuries result in an estimated cost of more than $8 billion annually.[7,41] In the Netherlands there is an estimated 67 000 presentations of cycling casualties at their Emergency Departments (ED) per year and 8 000 hospital admissions.[3] In South Africa, an average of 300 cyclists are killed whilst cycling, each year.[17] During 2010 alone, 252 cyclists were killed and an estimated 800 more were injured in South Africa.[42]

This is not an isolated South African problem. There are a significant number of traffic deaths due to bicycle injuries each year in both the Netherlands and Australia (185 vs 31 in 2009).[3] In an epidemiological study on sports-related injuries in children and youth, cycling had the highest number of injuries of any sport in Canada, accounting for 13.5% of all sports-related injuries.[43] In a cross-sectional study, it was reported that bicycle riding had the highest absolute number of injuries per year (614 594 injuries) compared to the absolute number of injuries per year sustained from common sports.[7,44] In France, over the period 1996-2008, the mean incidence of injured cyclists was 80/100 000.[11] The incidence of injured cyclists who visited ED was 122/100 000 and 398/100 000 in Australia and Sweden respectively.[11] These types of detailed statistics on traffic deaths due to bicycle injuries and sports-related cycling injuries are not available in South Africa.

In road cycling, the absolute injury event rates per kilometre range from 26 to 68 times higher compared to motor vehicle travel.[1] In British Columbia, major trauma related to road cycling occurs at an annual incidence of 49.8 per 100 000 (2.9% of all trauma admissions), with the greatest number of road cycling deaths occurring due to neurotrauma.[1] On the contrary, mountain biking injuries accounted for only 1.6% of all severe trauma patient admissions in this area from 1992 to 2002 (about 1 – 6 injuries per 100 000 patients per year).[1]

However, these injury rates appear to vary between events. Over the six editions of the italian Nove Colli road cycling race, only 1.7% of participants asked for medical assistance and 0.2% did not finish the race for medical reasons.[2] During the 2006 Hamburg UCI Cyclassic, 1.0% of the 18,788 participants reported injuries and 0.4% were hospitalised.[2] In the 2007 Cyclassic, 0.8% of the 19,415 participants reported an injury and 0.3% were hospitalised.[2] The frequency of injuries in amateur road cycling races can be considered lower compared to professional elite cyclists participating in the 2007 Cyclassic, where 1.8% of 167 cyclists were hospitalised, resulting in an frequency rate of 0.116/1000 km of race.[2] In a descriptive epidemiological survey, it was found that over a period of six years of training and competition (2003-2009), amongst 51 elite cyclists, the rate of traumatic injuries was 0.007/1000 km.[45] A prospective study, over a six day cycle tour, investigated the incidence of and risk factors for bicycle injuries among riders participating in the Cycle Across Maryland tour.[46] A total of 198 injuries were documented amongst the 1638 riders in the tour. Of these, 42.9% were acute traumatic (15.4 per 100 000 person-miles), 38.4% were due to NTCIs (13.7 per 100 000 person-miles), and 18.7% were due to other medical problems (6.7 per 100 000 person-miles).[46]

2.2.2 *Classification of cycling injuries*

Cycling injuries are often classified as either traumatic or NTCIs. Some studies classify NTCIs as overuse injuries.[6,8,20,47] NTCIs are defined as those injuries without a specific, identifiable event responsible for their occurrence.[20,48] NTCIs are the result of a cumulative process of tissue damage rather than instantaneous energy transfer.[6,20,49-50]

2.2.3 *Traumatic injuries*

Traumatic injury is a term which refers to physical injuries of sudden onset and severity which requires immediate medical attention.[51] The majority of traumatic injuries in racing involve soft tissue and skin, followed by fractures and concussions.[1-2,6] Traumatic cycling injuries tend to primarily affect the upper extremity and head, but also may affect the lower body.[1-3,6] Although superficial soft tissue injuries and musculoskeletal strains are the most common injuries, head injuries are responsible for the most fatalities and long-term disabilities in cycling.[41,52] Bicycle crashes may

result from numerous factors, including poor infrastructure or road conditions, mechanical failure, operator error, or interaction with a motor vehicle.[1,6] Table 2.1 presents the main anatomical areas and specific type of traumatic injuries sustained by cyclists.

Table 2.1: Main anatomical areas of traumatic injuries sustained by cyclists

Main anatomical area	Injuries
Head	Skull fracture, concussion, brain contusion, intracranial haemorrhage.[5-6,9,53-59,63-64]
Face/ eye	Contusions, facial fractures, dental fractures, corneal foreign bodies.[5-6,41,53-60,63-64]
Musculoskeletal	Fractures, dislocation, strains.[5-6,9,12,41,47,53-60,63-68,71]
Chest	Rib fractures, parenchymal lung injury.[5-6,53-57,59-60,63-64]
Abdomen	Splenic rupture, hepatic laceration, renal contusion, pancreatic trauma, vascular perforation, small or large bowel contusion, traumatic hernia.[53,55-57,59,62-64]
Genitourinary	Urethral and vulval trauma, rectal trauma, pelvic fractures.[6,9,12,41,56,61,65-66,69-71]
Skin and soft tissue	Abrasions ("road rash"), lacerations, contusions.[5-6,9,41,47,53,55,57,64]

2.2.4 Non-traumatic injuries

Non-traumatic injuries are defined as those injuries without a specific, identifiable event responsible for their occurrence.[6,20,48-50] Non-traumatic injuries are thought to be the predominant injury type in sports that involve long, repetitive training sessions (cycling, swimming and long-distance running).[6,20,48-50] Non-traumatic injuries are also seen in technical sports that involve the repetition of similar movement patterns (throwing and jumping sports).[6,20,48-50] The process starts when repetitive excessive loading results in damage to a specific structure such as tendons or bone.[72] With sufficient recovery time, the tissue is able to adapt to the load placed on it and able to undergo further loading without injury.[72] Without adequate recovery, micro trauma develops and stimulates the body's inflammatory response, causing the release of vasoactive substances, inflammatory cells, and enzymes that damage local tissue.[73] Cumulative micro trauma from further repetitive loading ultimately causes clinical injury.[72] In chronic or recurrent cases, continued loading can result in degenerative changes leading to weakness, loss of flexibility, and chronic pain.[74]

Thus, in non-traumatic injuries the problem is often not acute tissue inflammation, but chronic microscopic damage and failed healing response.[72] The onset of non-traumatic

injury symptoms and disability is gradual and the point at which they can be called an "injury" is blurred.[47] Not a lot is known about the true extent and severity of non-traumatic injuries in sports, largely because of the methodological challenges involved in recording of the non-traumatic injuries.[47] Multiple variations of the definition of non-traumatic injuries and reporting of non-traumatic injuries hamper the interpretations and comparisons of results.[75] Limited records of non-traumatic injuries are available for study as non-traumatic injuries are frequently not severe enough to cause an individual to seek medical care.[75] Traditional injury screening systems, which rely mostly on a clearly identifiable onset and which use the duration of time-loss from sport as the sole means of measuring the severity of the non-traumatic injury, may be inappropriate for studying non-traumatic injuries.[47] These screening systems may be inappropriate as not all non-traumatic injuries cause time-loss from sport and athletes often continue to train and compete despite the existence of non-traumatic injuries.[47]

Various epidemiological studies have been undertaken in an attempt to describe the injuries occurring in cyclists. When trying to integrate the various results from these studies it becomes difficult to do so, as they differ in observation time, type of cyclist and type of event. In an epidemiological study on 65 male professional road cyclists (aged between 21 - 32) between 1983 and 1995, the common injuries were due to non-traumatic mechanisms (68%) instead of trauma.[76] The cyclists competed for two professional cycling teams, participating in different road cycling races held across Europe.[76]

An epidemiological study, observing cyclists over one season, revealed that 58.3% of the studied 109 top-level cyclists reported 94 NTCIs, for which they received medical attention.[20] In another epidemiological study done on 294 male and 224 female recreational cyclists, 85% of cyclists reported one or more NTCIs.[40] Of the injuries that was reported, 36% were serious enough for the cyclist to have sought out medical treatment.[40] These differences may be due to the different methods utilised in the studies for collecting data and the different characteristics of the races (length, elevation and atmospheric conditions). In the United States roughly 23 million cyclists develop at least one NTCI in their lifetime.[52] NTCIs may contribute to a variety of musculoskeletal complaints, compression neuropathies, perineal and genital complaints.[41] In an American prospective study, 87% of the 1140 responders who

completed a post-ride survey after having cycled 546km over 6 days in the Cycle Across Maryland tour, reported one or more non-traumatic musculoskeletal injuries.[46]

Non-traumatic injuries present a common but complex diagnostic and rehabilitative challenge in many sports and activities.[51] The most common NTCI sites in road cycling are the knee and ankle, back, neck and shoulders, hands and wrists and the buttock and perineum.[6,8,12,15,20,40,46,65,75-81] Investigations on the prevalence of NTCIs amongst participants of non-competitive recreational cycling events found knee injuries to be most frequent, affecting between 24% and 62% of subjects.[40,46,65,82] In the same studies other injuries are more variable, as lower back pain (LBP) had prevalence rates of 3% to 31%, neck pain had prevalence rates of 3% to 66%, shoulder pain had prevalence of between 9% to 30%, buttocks pain had a prevalence between 9% to 42%, and lower leg/foot pain had a prevalence between 7% to 24%, respectively,[40,46,65,82] There is limited data on the NTCIs of amateur cyclists preparing for participation in a 1-day cycle challenge. In a cross-sectional study done on a one day cycle challenge, the most common NTCIs sites were the back 41%, hand/wrist 41%, buttock/perineum 41%, neck 34%, knee 33%, foot/ankle 24% and hip 7%.[39]

Table 2.2 presents the main anatomical area and specific type of NTCIs.

Table 2.2: Main anatomical areas of NTCIs:

Main anatomical area	Injuries
Neck and back	Cervical strains, lower back pain.[6,9,41,47,65-67,71]
Handlebar neuropathies	Ulnar nerve (deep palmar branch), median nerve.[6,47,60,63,65,67-68]
Saddle	Skin chafing, ulceration, irritation (saddle sores), ischial tuberosity pain, fibromas, pudendal neuropathies, impotence, urethral trauma (urethritis, haematuria), vulval trauma.[5-6,9,12,41,57,61,65-66,69-70]
Hip	Trochanteric bursitis, iliopsoas tendonitis.[5-6,9,47,65]
Knee	Patellofemoral syndrome.[5-6,9,41,47,53,56,65]
Foot / ankle	Metatarsalgia, plantar fasciitis, Achilles tendonitis, paraesthesia's.[5-6,9,41,47,53,56,65]

2.2.4.1. NTCIs of the knee and ankle

NTCIs of the knee are very common and the most likely cause of time lost in cyclists.[6,8-9,15,39,62,68,79-81,83-84] In a cross-sectional study, it was documented that 33% of cyclists

experienced knee problems whilst preparing for participation in a one day cycle challenge.[39] Of these knee problems, 56% experienced anterior knee pain (AKP), 37% experienced lateral knee pain, 18% experienced medial knee pain and 6% experienced posterior knee pain.[39] In a cross-sectional study on 109 professional road cyclists, 23% of the respondents required medical attention for knee pain.[20] The main injuries are AKP, patellofemoral pain syndrome (PFPS), iliotibial band friction syndrome (ITBFS), chondromalacia, quadriceps tendinosis, patellar tendinosis, and patellar bursitis.[6,8-9,15,62,68,79-81,83-84]

The most common cause for chronic AKP in cyclists is PFPS.[6,8,15,20,36,76,79-81,83] PFPS is characterized by repetitive flexion and extension of the knee joint, resulting in peri-patellar pain.[51] Patellofemoral contact is at its maximum at 90° of knee flexion and decreases as the knee moves into an extended position.[79] During cycling, the forces that are generated by the contractions of the quadriceps muscles during the downward stroke (knee extension) are transferred to the patellofemoral joint. This patellofemoral joint reaction force is thought to damage the peri-patellar structures, resulting in the NTCI.[15,20,79-80,83] In a descriptive epidemiological study, 63.4 % of the historical group (65 professional road cyclists surveyed from 1983 to 1995), reported NTCIs of the knee.[36] AKP was found in 57.7 % of the injuries, with patellofemoral chondropathy being the most frequently diagnosed entity.[36] In the same study, 36.9% of the current group (65 top-level road cyclists reporting injuries occurring from 2000 to 2009), reported NTCIs of the knee.[36]

The risk of PFP in cyclists is increased by training errors such as the rapid increases in training volume, the incorrect use of the bicycle gearing (cycling in too high a gear) and increased hill or climbing training.[15,20,79-81,83] Evidence shows that the incorrect pedal or foot line (possibly caused by the type of cycling shoes and cleats used); the incorrect bicycle set-up (such as incorrect frame size, the saddle height being too high or too low and an incorrect saddle position); the muscle imbalances (quadriceps, hamstring and hip stabiliser muscles); and anatomical abnormalities in the cyclist (small mobile patella, hypoplasia of the lateral femoral condyle and patella alta) contribute to PFP in cyclist.[15,20,79-81,83]

In a biomechanical analysis study using two-dimensional video analysis, conducted at the Sports Medicine Unit of the University of Cape Town, have shown that cyclists with patellae femoral pain exhibit an abnormal nonlinear pattern of knee movement during the downward stroke of cycling.[83] Reducing the loads on the patellofemoral joint and decreasing the risk factors of abnormal tracking pattern can be addressed by altering the extrinsic and intrinsic factors.[15,20,80,83]

Extrinsic factors include using custom-made orthoses, adjusting of the shoes and cleats, getting the correct bicycle set-up done, and biomechanical analysis of the downward stroke, may be required to reduce the loads on the patellofemoral joint. [15,20,80,83] Intrinsic factors include conditioning of the muscles imbalances and stretching of the overactive muscles.[15,20,80,83]

The most common cause of chronic lateral knee pain in cyclists is ITBFS.[6,15,20,79-81,83] This condition is characterized by repetitive mechanical friction between the iliotibial band and the lateral femoral condyle, with maximal pain felt at 30° knee flexion – the angle at which the ITB crosses over the femoral condyle (also called the ITB impingement angle).[6,15,51] In a biomechanical analysis study, it was found that the minimum knee flexion angle during cycling (at the bottom of the downward stroke) is close to the ITB impingement angle.[85] Decreasing the risk factors associated with ITBFS may include altering the extrinsic factors by adjusting the saddle height and correcting training errors; and addressing the intrinsic factors by conditioning of the muscles involved in hip stabilisation, and stretching of the tight and overactive muscles [80,83,85]

Biomechanical malalignment is also a contributing factor in NTCIs, and can cause patellofemoral tracking problems.[6,79] Biomechanical leg malalignment is caused by a Q angle greater than 20° and over pronation of the foot or hindfoot valgum.[51,79,81] The Q-angle is formed by a line from the anterior superior iliac spine, down the thigh, to the midpoint of the patella and a second line from the tibial tubercle to the midpoint of the patella.[51,79] A measurement of more than 20° has been associated with excessive external or internal tibial rotation or genu valgum or varum and is larger than what is considered to be the normal range (men= 12°-15° and women= 15°-18°).[51,79] Another

contributing factor to malalignment is over pronation of the foot or hindfoot valgum.[79] Over pronation of the foot causes a functional increase in the quadriceps angle (Q-angle), which may leads to muscle imbalance and patellofemoral malalignment.[15] Decreasing the risk factors associated with malalignment may include altering the extrinsic factors: modification of the cyclist's foot position to compensate for the anatomical malalignment such as modifying the equipment to help redirect the forces transferred to the lower extremity, changing the rotation, length, and positioning of the cleats, and a custom-made orthotic device can be inserted into the cyclist's shoes.[79]

NTCIs of the ankle can be a problematic injury in cyclists.[6,8,15,36,39,76,79,81] Foot and ankle problems were reported by 24% of cyclists whilst preparing for participation in a one day cycle challenge.[39] Of these, 60% reported numbness of the foot, 47% reported pins and needles of the foot, 20% reported pain in the foot, 9% reported pain in the ankle, and only 3% reported weakness of the foot.[39]

Achilles tendinopathy is the most common ankle injury reported to occur amongst cyclists.[6,8,15,36,76,79,81] Achilles tendinopathy is a non-traumatic injury of the Achilles tendon, the band of tissue that connects the calf muscles at the back of the lower leg to the heel bone.[51] Risk factors for Achilles tendinopathy in cyclists are increased by improper technique which could include the repetitive dorsiflexion during the power phase of the pedalling cycle, exerting too much force during hill-climbing, incorrect warm-up, and biomechanical malalignments.[6,8,15,76,79,81] The swelling in the ankle, due to the tendinopathy, causes a decrease in range of motion of the ankle. Normal ankle range of motion (plantarflexion = 45°- 65° and dorsiflexion = 10°- 30°) is important in cycling and specifically the prevention of ankle injuries.[6,15,51,79,81] During cycling the ankle is mainly in a plantar flexed position and rarely in a dorsiflexed position.[6,15,51,79,81] Decreasing the risk factors associated with Achilles tendinopathy may include altering the extrinsic factors by using felt heel pads for both feet and/or correcting the intrinsic factors by doing functional stretching and strengthening exercises for the Achilles tendon.[6,79,81,84]

2.2.4.2. NTCIs of the lower back

LBP is a common NTCI and defined as pain in the lower back or lumbar region, and it may be intermittent or constant.[4,6,9-10,31,47,81,83] It is usually the result of the prolonged flexed position while cycling which is needed to help maintain an optimal aerodynamic cycling position, as well as an appropriate degree of hip flexion for optimal force generation during cycling.[4,6,9-10,31,47,81,83] Increases in intra disc pressure have been shown with extended periods of sitting, especially in a flexed position, thereby predisposing the cyclist to LBP.[4,6,31] The causes of chronic LBP can be associated with intervertebral disc compression, traction on the facet joint capsules, and traction resulting in muscle strain or ligamentous sprain.[4,6,31] In a cross-sectional study observing cyclists over one season, it was proposed that a variant of chronic compartment syndrome may develop in the back extensor muscle groups, in some cyclists.[47]

LBP appears to be the leading cause of functional impairments and the main reason for cyclists to seek medical treatment.[15,20,47] In a cross-sectional study observing cyclists over one season, 45% of the respondents required medical attention for LBP.[20] In the same study, an annual prevalence for LBP of 58% was reported by professional road cyclists, during a specific season.[20] In another cross-sectional study in 89 participants taking part in a long distance cycle tour (4500 - 7242km over 80 days), a 15% injury incidence rate was reported.[4] In an epidemiological study, a 30.3 % LBP incidence rate was documented, during a one year period amongst 294 male and 224 female cyclists in California.[40] In three different studies using research questionnaires, the point prevalence statistics of LBP in cycling ranged from 10 - 60%.[4,28,40] In a cross-sectional study done on NTCIs of amateur cyclists preparing for participation in a one day cycle challenge, pain or neurological symptoms were reported by 88% of the respondents.[39] Of the respondents, 41% experienced back pain.[39]

Decreasing the risk factors associated with chronic LBP may include altering the extrinsic factors which may include getting the correct bicycle set-up done, such as adjustment of the saddle angle and height, adjusting the handlebar height, length and position; and working on the intrinsic factors such as conditioning of the muscles

involved in hip stabilisation, the lower abdominal and core muscles and improving overall hip and back flexibility.[47,83]

2.2.4.3. NTCIs of the neck and shoulders

A wide range of cyclists (10 - 66%) have also reported to experience pain in the neck and shoulders.[40,75] In a cross-sectional study done on a 500-mile, 8-day bicycle tour, 66.4% of the cyclists reported some neck or shoulder symptoms, while 20.4% of the cyclists reported significant neck or shoulder symptoms.[65,80] In an epidemiological study, it was found that 44.2% of male and 54.9% of female recreational cyclists presented for medical treatment of neck pain during a one year period.[40] In a cross-sectional study, it was documented that 34% of cyclists experienced neck pain whilst preparing for participation in a one day cycle challenge.[39] In another cross-sectional study, 10% of the respondents requires medical attention for neck pain.[20] Neck pain in cyclists is usually the result of muscle spasms (predominantly the levator scapulae and the trapezius muscles).[6,9-10,79,81,83] The risk of neck pain is increased by the constant hyperextension of the neck during cycling, weak upper back musculature, incorrect handlebar height, raised saddle height, and an incorrect cycling helmet to which the rider is not accustomed to.[6,10,79,83]

Decreasing the risks and causes of the NTCIs in the neck for cyclists may include altering some of the extrinsic factors. These alterations may include adjusting the bicycle mechanics (shortening of the handlebars, raising the handlebars, reducing the saddle height) and reducing the weight of the cycling helmet. Addressing possible intrinsic risk factors including the conditioning of the upper back muscles and stretching of the overactive muscles has been advocated.[79-80,83]

2.2.4.4. NTCIs of the hands and wrists

In the upper limbs, ulnar and median nerve compression appears to be the most common NTCIs.[46,77-78] In a cross-sectional study, it was observed that 92% of road and MTB cyclists experience either motor or sensory symptoms, or both during a four day, 600km cycle race.[77] Since the first 1200 km Paris-Brest-Paris cycling tour in 1891, the entrapment of the ulnar nerve has been identified.[12] Participating in multi-day cycling events may lead to chronic numbness and tingling of the hand, with linked weakness

of the muscles in the hand. [12,79,81,83,86] In a questionnaire based cross-sectional study on 260 participants cycling in a 540km one-stage tour, weakness of the hands was reported by 19% of the 169 respondents.[12] In another cross-sectional study, it was found that 36% of the 89 riders complained of hand numbness during a 7242km, 80 day cycling tour.[82] In a questionnaire based cross-sectional study on 3 300 respondents preparing for participation in a one day cycle challenge, reported hand and wrist (41%) problems.[39]

Ulnar nerve compression (cyclist's palsy or ulnar neuropathy) is the most commonly reported NTCI that causes symptoms in the ulnar nerve distribution and was first reported in 1896.[6,13,79,83,86] Carpal tunnel syndrome, caused by entrapment of the median nerve is also sometimes reported but, as the median nerve is less affected by the hand positioning on the bicycle bars, it has a lower prevalence rate than the ulnar nerve in cycling.[6,13,79,81,83] In a prospective study, it was found that 36% of the 25 riders participating in a 600km bicycle tour experienced motor weakness, 10% experienced sensory loss and 24% experienced both motor deficit and sensory loss in the hand.[77] The ulnar nerve is irritated by the increased pressure exerted on the hands, grasping the handlebars, especially when riding on rough terrain.[79] There is an increased risk of neuropathy during the hyperextended position of the hands on the handlebars, as this causes compression and stretching of the nerve as it passes from the wrist to the hand.[79] Decreasing the risk factors associated with hand pain may include addressing the extrinsic factors such as reducing the constant pressure and vibration on the arms and hand, getting the correct bike set-up done, wearing cycling gloves, adjusting the handlebar position, applying padding to the handlebars, frequently altering hand position during cycling, and the reduction of body weight on to the handlebars.[79,83]

2.2.4.5. NTCIs of the buttocks and perineum

Buttock and groin pain in cyclists is usually the result of the pressure of the saddle during prolonged sitting and can result in injury to several anatomical areas.[6,12,68,79,83] These injuries can include saddle sores (pressure sores), perineal folliculitis and furuncles, callosities, subcutaneous fibrosis, ischial bursitis and subcutaneous perineal cystic nodules.[6,14,79,83] Male cyclists can present with numbness or tingling in the scrotum or the penis due to the development of pudendal neuropathy. It has been

documented that prolonged compression of the pudendal nerve, usually following repeated cycling or multi-stage events, can result in transient impotence in male cyclists.[6,14,79,83] This has also been documented in a long one-stage 540km Norwegian cycle tour.[12] In this tour, 33 of the 160 male respondents (21%), aged 23-54, had numbness of the genitals, and it lasted for a whole day or more in 12%. Whether this will occur in shorter one-day cycling events is still unknown. Traumatic urethritis and torsion of the testis have also been described.[79-80,83] In female cyclists a range of sexual and urinary symptoms and vulval trauma may be experienced.[14] This can include superficial abrasions, lacerations, contusions and haematomas. A cross-sectional study reported that approximately a third of 282 female members of a bicycling club had experience of perineal trauma, 19% of which were associated with haematuria or dysuria, and 34% with perineal numbness.[87] In another cross-sectional study, the 1 358 respondents who were preparing for participation in a one day cycle challenge, complained of symptoms in the buttock/perineal area, 53% had pain, 49% had loss of sensation, 25% had pins and needles and 3% experienced erectile dysfunction.[39] Decreasing the risk factors associated with buttock and groin pain in cyclists may include addressing the extrinsic factors by using a modern, functionally designed saddle (may differ for sex), wearing padded cycling shorts that are cleaned daily, shaving of the perineal area to avoid adhesive friction on hair follicles, and adjusting the seat position and height to help distribute the pressure evenly while in a seated position.[79-80,83]

2.3 RISK FACTORS ASSOCIATED WITH NTCIS

The principles of preventing and managing NTCIs rely, firstly, on establishing a detailed anatomical and pathological diagnosis of the injury and, secondly, identifying the underlying intrinsic (related to the cyclist) and extrinsic (related to the bicycle and the environment) risk factors associated with the NTCI.[20,83] The identification of possible risk factors assists practitioners in addressing these risk factors in an attempt to prevent the injuries.

NTCIs most commonly result from overload or repetitive micro trauma stemming from intrinsic and extrinsic factors. Overtraining occurs when the body's musculoskeletal system is stressed beyond the musculature and soft tissue's capabilities.[51,79] This

tends to occur, especially at the start of a cycling season, when trying to ride too many kilometres or cycling too many hills in a too high gear.[51,79] The motion of cycling mainly occurs in the sagittal plane, this may lead to strength imbalances and predispose cyclist's to develop an injury along the kinetic chain.[6] Muscle imbalance, especially among recreational cyclists, is often the result of general muscle weakness and being unaccustomed to the demands placed on the body whilst cycling.[6,15,51,79] In elite cyclists, the quadriceps muscles are often overactive compared to the hamstring muscles.[6,51,79] Hip abductor weakness has previously been linked with cycling injuries, and the gluteus medius has been shown to have abnormal activation patterns in the lateral ankle sprain, PFPS, ITBFS, and anterior cruciate ligament (ACL) injury.[6] In both recreational and elite cyclist, muscle (tensor fasciae latae muscles, hamstring muscles, quadriceps muscles, cervical and lumbar paraspinal musculature, gastrocnemius-soleus complex) inflexibility contributes to the increased risk of NTCIs, as shortened muscles do not react well to the stress placed on the body during cycling.[6,8,15,51,79]

Table 2.3 presents the intrinsic and extrinsic risk factors associated with NTCIs.

Table 2.3: The intrinsic and extrinsic risk factors associated with NTCIs

Type	Risk factor
Intrinsic risk factors 9,15,46-47,51,53-54,56,58-59,63-66,70-72	Older age Female gender Body composition Anatomical malalignment (include pes planus, pes cavus, hyperpronation, tibial torsion, patellofemoral malalignment, femoral anteversion, and leg-length discrepancy). Muscle inflexibility (tensor fasciae lata muscles, hamstring muscles, quadriceps muscles, cervical and lumbar paraspinal musculature, gastrocnemius-soleus complex). Muscle imbalance. Inexperience. Lack of conditioning before riding. Growth (susceptibility of growth cartilage to repetitive stress). Prior injury. Menstrual dysfunction. Psychological factors (maturity level, self-esteem).
Extrinsic risk factors 9,15,46-47,51-53,55-57,59-68,71	Training errors. Poor performance. Incorrect techniques. Unsuitable surfaces. Overtraining (too-rapid training progression and inadequate rest). Adult or peer pressure.

2.3.1. Intrinsic risk factors associated with NTCIs

Intrinsic factors are the characteristics of the individual sport or exercise participant, and include demographic characteristics, anatomic factors, physical fitness and health risk behaviours. Intrinsic risk factors that have been associated with NTCIs include age, gender, training, anatomical malalignment, professional bicycle fitting, muscle inflexibility, muscle imbalance, lack of conditioning before riding, prior injuries, menstrual dysfunction and psychological factors.[6,9,36,39-40,46,65,75,88-89] The following intrinsic factors will be reviewed in this section: Demographics (age group and gender), cycling training / racing history, history of chronic disease and history of medication use.

2.3.1.1. Age

Age has been shown to be a risk factor for numerous diseases for example, osteoarthritis.[90-92] Age is also a risk factor for lower extremity injuries, as older athletes typically have increased risk exposure over time compared to younger athletes having less exposure.[90] Increased injury incidence has been reported with increased age among soccer players,[93-96] Australian football players,[97] recreational athletes,[98] and military recruits.[99] In two studies it has been suggested that younger age is a risk for development of medial knee pain, back, buttocks, and upper leg complaints in cyclists.[46,65] While in another study, older age was identified as a risk factor for seeking medical care for a cycling injury.[9] However, in a cross-sectional study on cyclists preparing for participation in a one day cycle challenge, no relationship between age and any susceptibility to cycling injury was found.[39]

2.3.1.2. Gender

It is well documented that female athletes sustain more knee injuries than male athletes, especially ACL sprains.[100-109] The effect of gender on ankle specific injuries and lower extremity injuries as a group is less clear than the relation between gender and knee ligament injuries.[90] It has been suggested that female cyclists have an increased risk for developing NTCIs, particularly in the neck (1.5 times) and shoulder (2.2 times), and the medial knee.[39-40,65] However, in two studies, no significant differences in injury risk at various anatomical sites was found between male and female cyclists.[40,65]

2.3.1.3. Cycling training / racing history

The following specific cycling training / racing history variables are possible risk factors associated with NTCIs: years of recreational cycling, years of participation in distance cycling events of > 2 hours, average number of training sessions per week in the last 12 months, average weekly distance in the last 12 months, average training speed in the last 12 months, and average racing speed category.

There is some evidence that increased weekly training and increased racing frequency is associated with the development of NTCIs.[40] In a cross-sectional study, it was found that participants were 2.3 to 4 times more likely to be treated for an overuse injury during the tour if they usually bicycled less than 26 miles (41.8 km) per week in preparation for the tour.[46] It has been suggested that cyclists with less years of cycling experience had more buttock and groin complaints.[40,65] However, in one study, no relationship was evident between long distance riding experience and any other NTCIs.[65] In one study, using univariate analysis, a slower race cycling speed was also associated with a 1.9 to 3.5 times more likely chance to be treated for an overuse injury during the tour if they usually rode at less than 14 miles per hour (22.5 km/h).[46]

2.3.1.4. History of chronic disease

Numerous markers for a history of chronic disease are possible risk factors associated with NTCIs: a history of existing Cardiovascular disease (CVD), risk factors for CVD, symptoms of CVD, respiratory disease, endocrine disease, Gastrointestinal tract (GIT) disease, nervous system or psychiatric disease, kidney or bladder disease, haematological system disease or immune system disease, cancer, and allergies.

As far as it could be established from the current literature review, the association between underlying chronic disease and NTCIs in recreational cyclists have not been explored before. However, underlying chronic disease (hypertension, heart disease, diabetes, asthma, cardiac arrhythmia, malignancies) has been reported in recreational cyclists, with a prevalence of chronic disease that varies between 10% to 16%.[40,65]

2.3.1.5. History of medication use

Medication types used that could increase the risk of medical complications during endurance races include the use of chronic disease prescription medication, and the use of AAIM.[110] In a cross-sectional study on 109 professional road cyclist, 13.8% of cyclists used nonsteroidal anti-inflammatory medication (NSAIDs) for LBP and 18.3% used NSAIDs for AKP, in the previous 12 months.[20] As far as it could be established from the current literature review, the association between AAIM medication use and NTCIs in recreational cyclists has not been explored before.

Table 2.4 presents the intrinsic risk factors associated with NTCIs with possible injury specific prevention strategies.

Table 2.4 Intrinsic risk factors associated with NTCIs with possible injury specific prevention strategies

Anatomical site	Non-traumatic cycling injury	Intrinsic risk factor	Prevention strategy
Knee	Anterior knee pain (patellofemoral pain, patellar or quadriceps tendinopathy)	• weak hip abductors/gluteus medius, • weak vastus medialis, • excessive foot pronation, • valgus alignment, • patellar laxity or tilt	• Quadriceps strengthening • Stretching focused on loosening potentially tight anatomical structures (hamstrings and quadriceps). • Specific warm-up and cool down sequences • Core stability • Hip strengthening
	Iliotibial band friction syndrome	• varus alignment, • weak hip abductors, • prominent lateral femoral condyle, • ITB tightness / positive Ober's test	• Avoid excessive hills • Proper saddle adjustment • Cleat adjustment • Strengthen hip abductors
	Biceps femoris tendinopathy	• varus alignment	• Correct leg length discrepancy • Adjust your cleats in the case of having wider hips or Q-angle • Orthotic usage to address flat feet • Ensure enough rest and avoid overtraining • Eccentric strengthening exercises • Stretching to improve range of motion
Ankle	Achilles tendinopathy	• pes planus, • foot hyperflexibility, • leg length discrepancy of >2cm • limited dorsiflexion <10°	• Correct leg length discrepancy with shim • Stretching to improve range of motion

Anatomical site	Non-traumatic cycling injury	Intrinsic risk factor	Prevention strategy
Foot	Foot numbness and pain (metatarsalgia, interdigital neuralgia, plantar fascitis)	• prominent metatarsal heads, • morton's neuroma, • peripheral polyneuropathy	• Pay attention to shoe fit. ▪ Keep the thickness of your socks consistent ▪ Pay attention to the cleat plate • Check your bike position ▪ Alternate between sitting and standing ▪ Incorporate a few stretches for the hamstrings and piriformis
Back	Low back pain (lumbar discogenic pain and radiculopathy)	• degenerative disc disease, • disc herniation, • poor postural habits off the bike, • dural tension • limited hamstring ROM • weakness of the core • weakness of the upper back • leg length discrepancy of >2cm	• Correct leg length discrepancy with shim • Strengthen of lumbar pelvic stabilizers and core • Stretching to improve range of motion
Neck and Shoulder	Neck pain (cervical Radiculopathy facet-mediated pain, myofascial pain)	• degenerative disc disease • disc herniation, • thoracic kyphosis, • poor posture – forward head and neck posture, rounded shoulders, • weakness of the core • weakness of the upper back, • weakness of neck extensors	• Keep your chest up and chin down, maintain a straight line through your spine as much as possible • Elbows should be unlocked, a slight bend at the elbows acts as a shock absorber • Change your hand position regularly to reduce muscle fatigue • Regularly stretch your neck during more relaxed parts of the cycle • Adjust saddle tilt, if the saddle is tilted too nose down your upper trapezius and shoulder muscles will work unnecessarily to support your weight leading to early fatigue

Anatomical site	Non-traumatic cycling injury	Intrinsic risk factor	Prevention strategy
Hands and Wrists	Hand numbness (ulnar neuropathy, carpal tunnel syndrome)	• history of carpal tunnel syndrome or ulnar neuropathy • Limited hand grip strength	• Adjust the saddle height, angle and position • Adjust handlebar height, width and position • Ensure wrists are in line with the forearm • Move your hands regularly during cycling to increase blood flow • Finger flexion exercises • Finger squeezes • • Grip strengthening exercises
Buttock and Perineum	Buttock pain (ischial bursitis, proximal hamstring tendinopathy, saddle sores)	• tight or weak hamstrings, • decreased hip range of motion, • history of buttock trauma/injury	• Hamstring strengthening • Stretching to improve range of motion
	Genital pain / numbness (pudendal neuralgia)	• obesity, • superficial course of nerve	• Get a wider seat that has extra padding • Wear padded bike shorts • Raise the seat or angle it downward to relieve pressure on the perineum • Change position or take breaks from time to time while riding
Hip	Lateral hip pain (trochanteric bursitis, gluteal tendinopathy)	• weak hip abductors, • tight lateral structures / positive Ober's test • leg length discrepancy of >2cm	• Correct leg length discrepancy with shim • Strengthen hip abductors • Stretching to improve range of motion
	Hip joint pain	• underlying osteoarthritis or labral tear, • femoroacetabular impingement, • weak hip abductors • leg length discrepancy of >2cm	• Correct leg length discrepancy with shim • Strengthen hip abductors • Stretching to improve range of motion

(Adapted from Dettori et al.[75], Holmes et al.[88], Silberman et al.[89] and Kotler et al.[6])

From Table 2.4, it can be ascertained that the main intrinsic risk factors for NTCIs are anatomical malalignment, muscle inflexibility, muscle imbalance, cycling and training inexperience, lack of conditioning before riding, susceptibility of growth cartilage to repetitive stress, prior injuries, menstrual dysfunction and psychological factors.

2.3.2. Extrinsic risk factors associated with NTCIs

Extrinsic aspects including route characteristics, cycling surfaces, unsuitable training practices, equipment used, environmental conditions, and adult or peer pressure may increase the risks of sustaining a NTCI.[6,75,88-89]

Table 2.5 presents the extrinsic risk factors associated with NTCIs with possible injury specific prevention strategies.

Table 2.5: Extrinsic risk factors associated with NTCIs with possible injury specific prevention strategies.

Anatomical site	Non-traumatic cycling injury	Extrinsic risk factor	Prevention strategy
Knee	Anterior knee pain (patellofemoral pain, patellar or quadriceps tendinopathy)	• harder gearing, • lower pedalling speed (rpm), • hill climbing, • elevated training volume or distance • saddle too low, • saddle too anterior, • crank length too long, • foot pronation, • inadequate foot support (incorrect cleats)	• proper saddle adjustment • wearing custom orthotics • adjustment of cleats • gear down, especially early in season • use floating pedal system
	Iliotibial band friction syndrome	• incorrect gearing and constantly cycling in a high gear, • lower pedalling speed (rpm), • hill climbing, • elevated training volume or distance	• avoiding excessive hills • proper saddle adjustment • adjustment of cleats

Anatomical site	Non-traumatic cycling injury	Extrinsic risk factor	Prevention strategy
		• saddle too high, • saddle too posterior, • cleats internally rotated • pedal position too narrow	
	Biceps femoris tendinopathy	• elevated training volume/mileage, • aggressive cross-training with weights or running • saddle too high, • saddle too posterior, • cleats internally rotated	• proper saddle adjustment • adjustment of cleats • tilt saddle anterior (10°–15°) • correct training periodization
Ankle	Achilles tendinopathy	• excessive plantarflexion/dorsiflexion during pedal stroke • saddle too high/posterior (also may occur with saddle too low), • cleat position too anterior, • cleats internally rotated, • shoes too soft, • requiring support	• adjust saddle to prevent excessive ankle dorsiflexion • move foot forward on pedal
Foot	Foot numbness and pain (metatarsalgia, interdigital neuralgia, plantar fascitis)	• longer rides with ill-fitting shoes • improper cleat placement (usually anterior), • ill-fitting shoes, • lack of pedal float	• adjust saddle to prevent excessive ankle dorsiflexion • proper shoe fit • use floating pedal system
Back	Low back pain (lumbar discogenic pain and radiculopathy)	• sitting behind ischial tuberosities • saddle-bar drop, • excessive lumbar flexion due to handlebar reach/drop, • posterior pelvic tilt due to saddle nose-up position	• proper adjustment of the cyclist fore-aft position • tilt saddle anterior (10°–15°)
Neck and Shoulder	Neck pain (cervical radiculopathy facet-mediated pain, myofascial pain)	• cervical hyperextension, • prolonged riding in drops or aero bars • excessive reach to handlebars, • low handlebar • position (saddle-bar drop)	• raise handlebars • use upright bars • move saddle closer to handlebars

Anatomical site	Non-traumatic cycling injury	Extrinsic risk factor	Prevention strategy
Hands and Wrists	Hand numbness (ulnar neuropathy, carpal tunnel syndrome)	• infrequent position change • supporting too much weight with arms, • lack of cushioning on bars or gloves, • handlebars too low or forward, • saddle tilted nose-down	• raise handlebars • reduce stem length • often changing hand position • wear padded gloves • reduce weight supported by arms
Buttock and Perineum	Buttock pain (ischial bursitis, proximal hamstring tendinopathy, saddle sores)	• infrequent position change / pressure relief, • running as cross-training • inappropriate saddle shape for the individual (typically too narrow), • lack of saddle padding, • saddle too high, • too much weight in the seat, • lack of padding or lubrication • sweating	• wider saddle • periodically cycle in a standing position • wear padded shorts / saddle • using powders and antiperspirant
	Genital pain / numbness (pudendal neuralgia)	• infrequent position change / pressure relief (i.e., standing to pedal), • indoor riding • inappropriate saddle type (typically too narrow), • excessive saddle tilt (often nose-up), • improper weight distribution between saddle and bars, • handlebars too high, • lack of saddle padding • lack of saddle cut-out • use of cut-out saddle for some cyclists	• wider saddle • periodically cycle in a standing position • wear padded shorts / saddle • tilt saddle nose down • using cut-out saddle • don't use cut-out saddle if it caused previous numbness
Hip	Lateral hip pain (trochanteric bursitis, gluteal tendinopathy)	• longer riding • saddle too high	• adjust saddle to prevent fascia lata chafing against trochanter • adjust saddle height

Anatomical site	Non-traumatic cycling injury	Extrinsic risk factor	Prevention strategy
	Hip joint pain	• trying to bring knees too close together during pedalling, • prolonged riding in drops or aero bars • improper cleat alignment (toed-in), • not enough cleat float, • cranks too long, • aero position too low/aggressive	• adjust saddle height

(Adapted from Dettori et al.[75], Holmes et al.[88], Silberman et al.[89] and Kotler et al.[6])

From Table 2.5, it can be ascertained that the main extrinsic risk factors for NTCIs are training errors, poor performance, incorrect training and cycling techniques, unsuitable training and cycling surfaces, overtraining and adult or peer pressure.

2.4 CONCLUSION

Cycling is a popular form of transportation, recreation, fitness and sporting activity amongst people of all ages.. Different type of cyclists ranging from non-competitive and recreational cyclists to elite professional cyclists participate at multi-stage or at one-day events. Due to the increased popularity of cycling there is an increase in the total number of injuries amongst cyclists which are causes of significant morbidity and mortality.

Cycling injuries are classified as either traumatic or NTCIs. NTCIs are defined as those injuries without a specific, identifiable event responsible for their occurrence, which are the result of a cumulative process of tissue damage rather than instantaneous energy transfer. NTCIs of the knee, specifically PFP and ITBFS, are very common and the most likely cause of time lost in cyclists. LBP is a common NTCI and appears to be the leading cause of functional impairments and the main reason for cyclists to seek medical treatment. Additionally a wide range of cyclists (10 - 66%) have reported experiencing pain in the neck and shoulders with ulnar and median nerve compression as the most common NTCI documented to occur in the upper limb.

The principles of preventing and managing NTCIs rely, firstly, on establishing a detailed anatomical and pathological diagnosis of the injury and, secondly, identifying the underlying intrinsic (related to the cyclist) and extrinsic (related to the bicycle and the environment) risk factors associated with the NTCI. Neither the epidemiology of NTCIs nor the risk factors associated with NTCIs in recreational cyclists have been well studied. The findings of this research are important for clinicians who consult with cyclists presenting with NTCIs, and it is important to develop and implement preventative strategies for NTCIs.

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CHAPTER 3: PAPER 1
EPIDEMIOLOGY, CLINICAL CHARACTERISTICS AND SEVERITY OF NON-TRAUMATIC INJURIES IN RECREATIONAL CYCLISTS: A CROSS-SECTIONAL STUDY IN 21824 CYCLISTS - SAFER XI

3.1. ABSTRACT:

Background: Information is lacking on the epidemiology, clinical characteristics and severity of non-traumatic (chronic, “overuse”) cycling injuries (NTCIs) in recreational cyclists.

Aim: To determine the prevalence, anatomical areas affected by, and severity of NTCIs in a large cohort of road cyclists participating in a community-based mass participation cycling event.

Design: Cross-sectional study

Setting: Cape Town Cycle Tour

Participants: Cycle race entrants

Methods: Of 35914 entered cyclists, 27349 completed an online pre-race medical screening questionnaire, and 21824 consenting cyclists (60.8%) were included. We report the crude (un-adjusted) lifetime prevalence, retrospective annual incidence, point prevalence (injured and non-injured), common anatomical areas/sites, specific NTCIs, tissue type affected and severity of NTCIs.

Results: The lifetime prevalence of NTCIs was 2.8%, with a 2.5% annual incidence of NTCIs and a 1.1% point prevalence at the time of registration. The most common main anatomical regions affected by NTCIs were lower limb (43.4%), upper limb (19.7%), lower back (11.5%), and hip/groin/pelvis (10.7%), with the knee (26.3%), shoulder (13.0%), and lower back (11.5%) as the most affected specific anatomical sites. The most common specific NTCI was AKP (14.2%), 55% of NTCIs were soft tissue injuries, 50% of NTCIs reported by cyclists had a symptom duration of >12 months and 37.3% of cyclists with NTCIs reported that injuries were severe enough to reduce/ prevent cycling.

Conclusion: One in 40 recreational cyclists report a NTCI each year, mostly affecting the knee, lower back and shoulder (50.8% of injuries). NTCIs negatively affect cycling (50% for >12 months and >37% injuries are severe enough to affect cycling). Risk

factors for NTCIs in recreational cyclists need to be determined to develop and implement injury prevention programs.

3.2. INTRODUCTION

The burden of non-communicable diseases (NCDs) of lifestyle can be reduced by a healthy lifestyle that includes participation in regular moderate- to high intensity physical activity for >150 min per week.[1-2] Mass, community-based participation in sport is therefore encouraged as part of a healthy lifestyle. The substantial growth in the popularity to participate in community-based endurance sports events is also evident in the South African context. Events such as the CTCT, multi-stage mountain-bike races (Cape Epic, Wine to Whales), distance running events (Comrades marathon, Two Oceans marathon, Cape Town marathon), swimming, triathlons (Iron Man, ITU World Triathlon series), canoeing and walking events are increasing in popularity with continuous growth in the number of participants. These events are usually held annually in a number of geographical locations in South Africa and attract large fields of elite and recreational athletes with varying ability.

Cycling is a popular form of transportation, recreation, fitness and sporting activity amongst people of all ages.[3-17] Due to the increased popularity of cycling and the nature of the activity, there is an increased number of injuries amongst both amateur and professional cyclists.[3-4,6-9,13,16-18] Non-traumatic injuries are the predominant injury type in sports that involve long, repetitive training sessions (e.g. cycling).[19]

In spite of the popularity of road cycling and the fact that some top level competitions, such as the Tour de France is one of the most televised sports events worldwide, literature is scarce on the epidemiology of NTCIs.[10] The literature on the epidemiology of NTCI is more abundant in mountain biking and triathlon modalities.[10] The limited epidemiological studies on NTCIs in road cyclist refer to leisure or transportation activities, and only a few epidemiological studies have been published on amateur and professional road cyclists engaged in training and competitions.[4] Most studies on NTCIs are in professional cyclists that attend training camps or during cycle tours ≥5 days[14,20-22] and little is known about NTCIs in mass-participation cycling events that attract recreational cyclists.[22-23]

Information is lacking on the true extent and severity of NTCIs in cycling events, largely because of the methodological challenges involved in recording of NTCIs.[24] The most common NTCI sites in road cycling are the knee and ankle, back, neck and shoulders, hands and wrists, and the buttocks and perineum.[8,10,14,17,20-23,25-31] NTCIs constitute a significant diagnostic and therapeutic problem because the symptoms are often diffuse and non-specific. A correct anatomical, pathological and functional diagnosis is essential to plan treatment for these injuries.[32] Furthermore, it is very important to identify risk factors associated with NTCIs in order to plan programs to assist athletes, trainers, and coaches to prevent NTCIs.[32]

The aim of this study was to document the epidemiology (lifetime prevalence, retrospective annual incidence and point prevalence), clinical characteristics (main anatomical region and specific anatomical sites affected, prevalence of specific common NTCIs, and NTCIs by tissue type affected), and severity (duration of symptoms, and severity grade) of NTCIs in recreational cyclists that entered for a large community based cycling event.

3.3. METHODS

3.3.1. Study design and ethical considerations

This study formed part of a series of on-going SAFER (**S**trategies to reduce **A**dverse medical events **F**or the **E**xercise**R**) studies.[33] The MSc Committee and Research Ethics Committee of the Faculty of Health Sciences of the University of Pretoria approved the study (REC numbers **431/2015** and **213/2017).** Data collection for the SAFER studies is ongoing, and this study was an analysis of data collected over a one-year period (2016). A descriptive cross-sectional design was used.

3.3.2. Participants and demographics

A total of 35 914 cyclists entered the 2016 CTCT, and 27 349 completed an online pre-race medical screening questionnaire. Of the cycle race entrants that completed the questionnaire, 21 902 gave informed consent for their data to be used for research purposes. Of the 21 902 consenting cycle race entrants 78 cyclists had missing or

incomplete data. Therefore, the final study population was 21 824 (60.8% of all cycle race entrants).

3.3.3. Data collection

3.3.3.1. Online medical questionnaire data

All cycle race entrants from the 2016 CTCT were required to complete an online medical questionnaire at the time of registration. The main reason for this questionnaire was for medical staff to have access to medical data for care on race day. In addition, the medical data were used for risk stratification and targeted personalized educational intervention to reduce the risk of medical complications.

The on-line medical screening tool consisted of a series of questions that were developed to specifically provide clinical information for medical staff on race day. The main sections of the screening tool were based on the guidelines for cardiovascular evaluation of middle-aged / senior individuals engaging in leisure-time sport activities (Position stand from the European Association of Cardiovascular Prevention and Rehabilitation),[34], and our previous studies in distance runners.[35-36]. The detailed methodology of the on-line medical screening tool development and implementation was described in previous studies amongst endurance runners.[35-36] For the purposes of this study in cyclists, additional questions, specifically related to common medical complications encountered during cycling, were added. The final screening questions related to the cyclists' training and medical history including history of acute traumatic and NTCIs (current, or recent – last 12 months).

3.3.3.2. Definition of cyclists with NTCIs

In the medical screening tool, cyclists were asked the following specific question related to NTCIs: *"Do you or did you suffer from any symptoms of a CHRONIC (no accident) cycling injury (muscles tendons bones ligaments or joints) IN YOUR CYCLING CAREER?"*. The definition of an injury was as follows: "*An injury that is / was severe enough to interfere with cycling or require treatment e.g. use medication or require you to seek medical advice from a health professional".*

In response to a “yes” answer to this question, participants were required to complete additional questions as drop-down boxes that were related to the NTCI, including the following: past or current injury, side of the body the injury occurred (if applicable), anatomical site, type of anatomical structure, severity, duration of injury, and whether the injury was one of the more commonly known NTCIs.

An NTCI was reported by 617 cyclists and 29 cyclists reported more than one NTCI. Therefore, 617 cyclists reported a total of 646 NTCIs. The epidemiology of NTCIs is reported for the 617 cyclists with NTCI, while the clinical characteristics and severity of NTCIs is reported for the 646 NTCIs.

3.4. OUTCOME VARIABLES

3.4.1. Epidemiology of NTCIs

In this study, we report the following epidemiological outcome variables: lifetime prevalence of NTCI (% cyclists reporting NTCI in lifetime career of cycling), retrospective annual incidence of NTCI (% cyclist reporting NTCI in the past 12 months), and point prevalence of NTCI (% cyclist reporting a current NTCI). The lifetime prevalence of NTCI (% cyclists reporting NTCI in lifetime career of cycling) was determined in response to a yes answer for *“an injury in the cyclists cycling career”*. The retrospective annual incidence of NTCI (% cyclist reporting NTCI in the past 12 months) was determined in response to a yes answer for *“an injury in the past 12 months or currently”*. Point prevalence of NTCI (% cyclist reporting a current NTCI) was defined as those cyclists reporting a *“current injury”*.

3.4.2. Clinical characteristics of NTCIs

We report the clinical characteristic outcome variables for NTCIs as follows: main anatomical region and specific anatomical site of NTCIs, specific common NTCIs and NTCI by tissue type affected (muscle, tendon, ligament, bone, joint, nerve).

3.4.3. Severity of NTCIs

The severity of NTCIs were expressed by the duration of symptoms (0-3 months, 4-12 months and >12 months) and an injury severity grading (Grade I-IV) commonly used for "overuse" injuries in sport.[37] For the purposes of comparing the grading of injuries to that of other studies, we also report NTCI severity in two categories: a) less severe, where cyclists are still able to cycle and compete with no or minimal interference (Grade I and Grade II), and b) more severe, where the NTCIs interferes with the cyclists ability to, and even stop them from, training or competing (Grade III and Grade IV).

3.5. STATISTICAL ANALYSIS

All 2016 online medical questionnaire data were entered into an Excel spreadsheet (Microsoft 2010) and was analysed using the SAS 9.4 statistical program. The data for consented cycle race entries were used for analysis (n=21 824). Multiple injuries (n=646) were reported by 617 injured cyclists. The lifetime prevalence of NTCIs (muscles, tendons, bones, ligaments or joints), the retrospective annual incidence of NTCIs and the point prevalence were reported taking into account the correlation resulting from the same cyclist reporting multiple injuries.

The NTCIs in the main anatomical region, specific anatomical sites, specific common NTCIs, tissue and type of NTCIs were described with frequencies and percentages out of all NTCIs. The duration of symptoms (months) of NTCIs were categorized by durations of 0-3 months, 4-12 months, and >12 months and the frequency (%) were reported for each category overall as well as by main anatomical region.

3.6. RESULTS

3.6.1. Study participant demographics and the response rate

Table 3.1 outlines the demographics (age and gender) of all cyclists entering the 2016 CTCT, compared with the consenting cycle race entrants that were participants in this study. Although the response rate was acceptable, a post-hoc analysis was conducted

to determine if the participants in this study were indeed representative of all the cycle race entrants.

Table 3.1: Characteristics of all cycle race entrants and study participants (consenting cycle race entrants)

Characteristics		All cycle race entrants (n=35914)		Entrants consenting as study participants (n=21824)		p
		n	%	n	%	
Gender	Males	28311	78.8	17282	79.2	p=0.0390
	Females	7603	21.2	4542	20.8	
Age groups (years)	≤30	6453	18	3333	15.3	p<0.0001
	31 to ≤40	7814	21.8	4447	20.4	
	41 to ≤50	10583	29.4	6382	29.2	
	>50	11064	30.8	7662	35.1	

p: p-value

We note that in our study population, compared with all cycle race entrants as determined by the Chi-squared test, there were significantly more cyclists over 50 years old (p<0.0001), as well as more male cyclists (p=0.0390) (Table 3.1).

3.6.2. Epidemiology of NTCIs

The lifetime prevalence of NTCIs (muscles, tendons, bones, ligaments or joints) in this population of consenting cyclists (n=21 824) was 2.8% (95%CI: 2.6-3.1; n=617). The retrospective annual incidence of NTCIs was 2.5% (95%CI: 2.3-2.7; n=551). In cyclists that reported any NTCI at the time of registration, the point prevalence was 1.1% (95%CI: 0.9-1.2; n=230).

3.6.3. Clinical characteristics of NTCIs

3.6.3.1. Anatomical region and specific anatomical sites of NTCIs

The frequency of injuries (%) by main anatomical region and specific anatomical sites is depicted in Table 3.2.

Table 3.2. NTCIs by anatomical region and specific anatomical sites of NTCIs in cyclists (expressed as % of all NTCIs) (n=646)

Main anatomical region	Specific anatomical sites	n	% of all NTCIs
Head, Neck & Face	All	37	5.7
	Neck	28	4.3
	Head	7	1.1
	Face	2	0.3
Upper Limbs	All	128	19.7
	Shoulder	84	13.0
	Wrist	16	2.5
	Elbow	15	2.3
	Finger	11	1.7
	Upper arm	1	0.2
	Forearm	1	0.2
Trunk / Chest	All	16	2.5
	Back chest	9	1.4
	Front chest	7	1.1
Lower Back	All	74	11.5
Hip / Groin / Pelvis	All	69	10.7
	Hip	32	5.0
	Hip muscle #	26	4.0
	Groin	11	1.7
Lower Limbs	All	281	43.4
	Knee	170	26.3
	Achilles	22	3.4
	Hamstring muscle	18	2.8
	Foot	18	2.8
	Calf muscle	17	2.6
	Ankle	17	2.6
	Quadriceps muscle	11	1.7
	Shin / Lower leg	8	1.2
Other	All	41	6.4

n: number of injuries reported in the study
% Non-traumatic cycling injury frequency (%) of reported injuries in the study
# including gluteus / buttock muscles

The main anatomical regions in which cyclists reported the majority of NTCIs (% of all NTCIs) were in the lower limb region (43.4%), followed by the upper limb (19.7%), lower back (11.5%), and hip / groin / pelvis (10.7%). Head, neck and face injuries (5.7%) and trunk / chest injuries (2.5%) were the least commonly affected main anatomical regions. Within the main anatomical regions, the three most affected specific anatomical sites of NTCIs were the knee (26.3%, n=170), shoulder (13.0%, n=84), and the lower back (11.5%, n=74).

There was no difference in the frequency of all reported injuries between the right side (34.8%) and left side (33.4%) of the body. Of the reported NTCIs, 19.4% were both right and left, and in 12.4%, the side of injury was not reported.

3.6.3.2. Frequency of specific common NTCIs

A list of common NTCIs were included in the questionnaire and in 76.3% of injuries, cyclists reported a specific NTCI. The frequency (%) of specific common NTCIs is listed in Table 3.3.

Table 3.3. Specific commonly reported NTCIs (expressed as % of all NTCIs) (n=646)

NTCIs	n	% (of all NTCIs)
Knee - Patellofemoral pain syndrome / anterior knee pain	92	14.2
Lower back pain	68	10.5
Shoulder pain	61	9.4
Knee - Iliotibial band friction syndrome (ITBFS)	55	8.5
Hip joint pain	30	4.6
Neck pain	28	4.3
Hip muscle injury (including gluteus / buttock muscles)	23	3.6
Achilles tendon injury	22	3.4
Numbness in the hand / fingers	21	3.3
Foot or heel pain	19	2.9
Calf muscle injury	16	2.5
Hamstring injury	16	2.5
Elbow pain	15	2.3
Wrist pain	10	1.6
Quadriceps muscle injury	5	0.8
Groin / genital numbness	6	0.9
Saddle sores	6	0.9
Other	116	18.0
Missing data	37	5.7

n: number of injuries reported in the study
% Non-traumatic cycling injury frequency (%) of reported injuries in the study

The four most common reported NTCIs were PFPS / AKP (14.2%), LBP (10.5%), shoulder injury (9.4%) and the ITBFS (8.5%) respectively. Therefore, knee injuries accounted for 22.7% of reported NTCIs.

3.6.3.3. NTCIs by tissue type

The frequency (%) of NTCIs by tissue type is depicted in Table 3.4.

Table 3.4. NTCIs by tissue type in cyclists (expressed as % of all NTCIs) (n=646)

NTCIs by Tissue Type		n	%
Soft tissue	All soft tissue	355	54.9
	Muscle (e.g. strain)	123	19.0
	Tendon	107	16.6
	Ligament (e.g. sprain)	75	11.6
	Nerve (e.g. numbness during or after cycling)	50	7.7
Bone	Bone (e.g. bruise or stress fracture)	122	18.9
Joint	Joint (e.g. arthritis)	92	14.2
Other	Other	68	10.5
Missing data		9	1.4

n: number of injuries reported in the study
% Non-traumatic cycling injury frequency (%) of reported injuries in the study

The majority of NTCIs were to the soft tissues (muscle, tendon, ligament and nerve) (54.9%), and 35.6% of NTCIs were reported as musculotendinous. The specific tissue type in which cyclists reported the majority of NTCIs (% of all injuries) were muscle (19.0%), followed by bone (18.9%), and tendon (16.6%).

3.6.3.4. NTCI by tissue type in each main anatomical region

A further analysis of the frequency (%) of NTCIs by type of tissue in the main anatomical region is depicted in Table 3.5.

Table 3.5. NTCIs by tissue type in the main anatomical regions (expressed as % of NTCIs in the main anatomical regions) (n=646)

NTCIs by Tissue Type	Main anatomical region													
	Head, Neck & Face (n=37)		Upper Limbs (n=128)		Trunk / Chest (n=16)		Lower Back (n=74)		Hip / Groin / Pelvis (n=69)		Lower Limbs (n=281)		Other (n=41)	
	n	(%)	n	%	n	%	n	%	n	%	n	%	n	%
Muscle (e.g. strain)	10	27.0	16	12.5	1	6.3	21	28.4	20	29.0	52	18.5	3	7.3
Tendon	1	2.7	18	14.1	0	0.0	1	1.4	7	10.1	74	26.3	6	14.6
Ligament (e.g. sprain)	2	5.4	20	15.6	1	6.3	1	1.4	2	3.0	47	16.7	2	4.9
Nerve (e.g. numbness during or after cycling)	6	16.2	10	7.8	0	0.0	16	21.6	4	5.8	10	3.6	4	9.8
Bone (e.g. bruise or stress fracture)	7	18.9	41	32.0	12	75.0	9	12.2	12	17.4	24	8.5	17	41.5
Joint (e.g. arthritis)	2	5.4	13	10.2	2	12.5	13	17.6	15	21.7	45	16.0	2	4.9
Other	8	21.6	9	7.0	0	0.0	11	14.9	9	13.0	24	8.5	7	17.1
Missing data	1	2.7	1	0.1	0	0.0	2	2.7	0	0.0	5	1.8	0	0.0

n: number of injuries reported in the study

% Non-traumatic cycling injury frequency (%) of reported injuries in the study

The most common tissue affected by NTCIs in the lower limb was tendon (26.3%), whilst bone was the most common tissue affected by NTCIs in the upper limb (32.0%) and trunk / chest (75.0%). In the lower back, hip / groin / pelvis, and head, neck and face the most common tissue affected by NTCIs was muscle (lower back: 28.4%; hip / groin / pelvis: 29.0%; head, neck and face: 27.0%, respectively).

3.6.4. Injury severity of NTCIs

3.6.4.1. Duration of symptoms of NTCIs

The symptoms were categorized by duration as follows: 0-3 months, 4-12 months, and >12 months . The duration of symptoms categories of NTCIs is depicted in Figure 3.1.

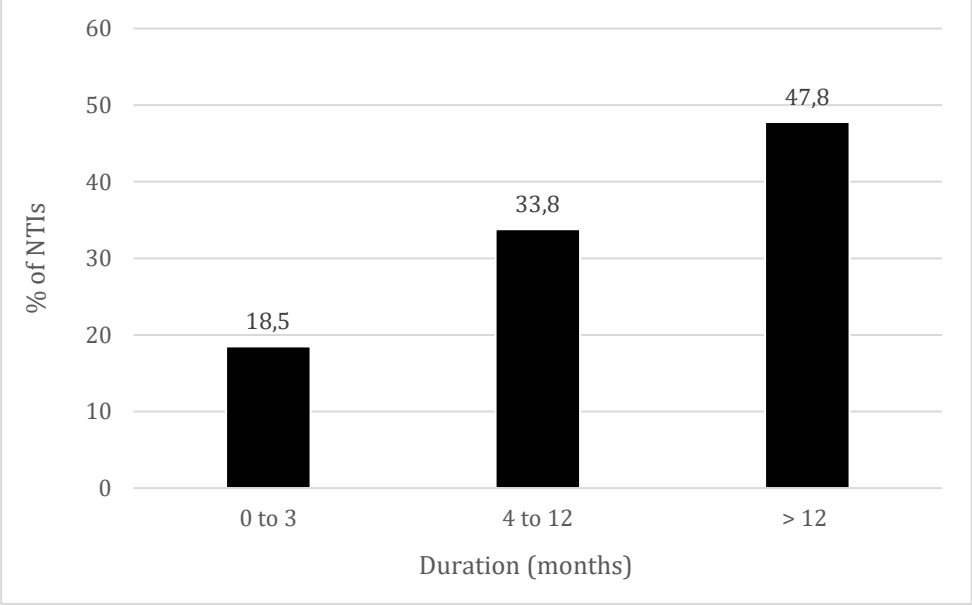

Figure 3.1: The frequency of NTCI's (% of all NTCIs) in each symptom duration category (0-3 months, 4-12 months, and >12 months)

The majority of NTCIs were injuries whose symptoms lasted more than 12 months (47.8%). Only 18.5% of the NTCIs reported had symptoms lasting less than 3 months (Figure 3.1).

The frequency (%) of NTCIs by duration of symptoms category is depicted in Table 3.6 (% of reported NTCIs by main anatomical region).

Table 3.6. NTCIs by duration of symptoms category (months) in the main anatomical regions (expressed as % of NTCIs in the main anatomical regions) (n=646)

Duration of symptoms category (months)	Main anatomical region													
	Head, Neck & Face (n=37)		Upper Limbs (n=128)		Trunk / Chest (n=16)		Lower Back (n=74)		Hip / Groin / Pelvis (n=69)		Lower Limbs (n=281)		Other (n=41)	
	n	(%)	n	%	n	%	n	%	n	%	n	%	n	%
0 - 3 months	3	8.1	32	25.0	5	31.2	13	17.6	6	8.7	51	18.2	9	22.0
4 - 12 months	12	32.4	45	35.2	8	50.0	17	23.0	19	27.5	95	33.8	22	53.7
> 12 months	22	59.5	51	39.8	3	18.8	44	59.5	44	63.8	135	48.0	10	24.4

n: number of injuries reported in the study
% Non-traumatic cycling injury frequency (%) of reported injuries in the study

Of the reported NTCIs by main anatomical region, 63.8% hip / groin / pelvis, 59.5% head, neck and face, and 59.5% lower back were reported as having a symptom duration of >12 months. Of the lower limb NTCIs 48.0%, and the upper limbs NTCIs 39.8% reported a symptom duration of >12 months. The minority of symptom duration of >12 months were reported in the trunk / chest (18.8%). The trunk / chest (31.2%) was the highest reported main anatomical region for symptom duration of 0 – 3 months, followed by the upper limb (25.0%), and lower limb (18.2%).

3.6.4.2. Injury severity (grading) of NTCIs

The frequency (%) of NTCIs severity (grade I – IV) of the NTCIs is depicted in Table 3.7.

Table 3.7. Injury severity (grade I – IV) of NTCIs (expressed as a % of all NTCIs) (n=646)

Severity grading of injuries			n	%
Less severe	All less severe (not affecting cycling)		361	55.9
	Grade I	I only experience symptoms after exercise	142	22.0
	Grade II	I experience symptoms during exercise. but it does not interfere with exercise	219	33,9
More severe	All more severe (affecting cycling)		241	37.3
	Grade III	I experience symptoms during exercise that may interfere with my training/ competition	183	28.3
	Grade IV	I am so painful that I may not be able to train or compete	58	9.0
Missing data			44	6.8

n: number of injuries reported in the study
% Non-traumatic cycling injury frequency (%) of reported injuries in the study

Of the reported injuries, 93.2% (n=602) reported severity grading and out of those, 40% (n=241) were severe enough to interfere with the cyclist's ability to, and even stop them from, training or competing.

The frequency (%) of NTCIs severity (grade I – IV) by main anatomical region is depicted in Table 3.8 (% of reported NTCIs by main anatomical region).

Table 3.8. NTCIs by injury severity (grade I – IV) in the main anatomical regions (expressed as % of NTCIs in the main anatomical regions) (n=646)

Severity grading of injuries		Main anatomical region													
		Head, Neck & Face (n=37)		Upper Limbs (n=128)		Trunk / Chest (n=16)		Lower Back (n=74)		Hip / Groin / Pelvis (n=69)		Lower Limbs (n=281)		Other (n=41)	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%
Less severe	All less severe	18	48.7	78	60.9	10	62.5	41	55.4	41	59.4	150	53.4	23	56.1
	Grade I	3	8.1	31	24.2	4	25.0	13	17.6	19	27.5	64	22.8	8	19.5
	Grade II	15	40.5	47	36.7	6	37.5	28	37.8	22	31.9	86	30.6	15	36.6
More severe	All more severe	15	40.6	40	31.3	2	12.5	30	40.5	26	37.7	114	40.6	14	34.2
	Grade III	13	35.1	23	18.0	1	6.3	22	29.7	17	24.6	95	33.8	12	29.3
	Grade IV	2	5.4	17	13.3	1	6.3	8	10.8	9	13.0	19	6.8	2	4.9
Missing data		4	10.8	10	7.8	4	25.0	3	4.1	2	2.9	17	6.1	4	9.8

n: number of injuries reported in the study
% Non-traumatic cycling injury frequency (%) of reported injuries in the study

The highest number of more severe (Grade III and Grade IV) NTCIs by injury severity were in the lower limbs (n=114). Of the reported NTCIs by main anatomical region, in the more severe NTCIs, over 40% of lower limbs (40.6%), head, neck & face (40.5%), and lower back (40.5%) were more severe. 37.6% hip / groin / pelvis, and 31.3% upper limbs were more severe NTCIs. The minority of trunk / chest (12.6%) were more severe NTCIs. Of the reported NTCIs by main anatomical region, the majority of NTCIs classified as less severe (Grade I and Grade II) were to the trunk / chest (62.5%), followed by upper limbs (60.5%) and hip / groin / pelvis (59.4%).

3.7. DISCUSSION:

The main findings of this study were 1) 2.8% of recreational cyclists reported a NTCI in their cycling career (about 1 in 35 cyclists), with an annual incidence of 2.5%, and a 1.1% point prevalence at the time of registration 2) the lower limb was the most common main anatomical region affected by NTCIs (43.4%), followed by the upper

limb (19.7%), lower back (11.5%), and hip / groin / pelvis (10.7%), 3) the three most affected specific anatomical sites of NTCIs were the knee (26.3%, n=170), shoulder (13.0%, n=84), and the lower back (11.5%, n=74), and the most common specific NTCIs was PFP / AKP (14.2%), 4) 55% of NTCIs were soft tissue injuries (muscle, tendon, ligament and nerve), and 5) almost 50% of cyclists with an NTCI reported a symptom duration of >12 months, 6) almost 60% of hip / groin / pelvis, head, neck and face, and lower back NTCIs were reported as having a symptom duration of >12 months 7) >37% of NTCIs were severe enough to reduce or prevent cycling (Grades III and IV), and 8) more severe NTCIs occurred mainly (>40%) in the lower limbs, head, neck and face, and the lower back.

3.7.1. Epidemiology of NTCIs in recreational cyclists

Although the epidemiology of NTCIs has been studied,[10-11,20,23,25,30,36-37] there are substantial methodological differences between studies, making comparisons difficult. The common methodological differences between studies include: differences in the definition of injury,[11,23,39], defining and reporting the exposure (annual incidence, incidence during single-day or multi-day staged races), small sample sizes,[11,23], low-response rates with possible selection bias[23,39], differences in the populations who were studied (ranging from professional cyclists to multistage cycling events)[10,20,31,38], and use of self-reported data with differences in timing and content of questionnaire administration[11,23,39]. The annual incidence of NTCIs has only been reported in a few studies, and varies between 17% to 88% [10,20,23,31,38-39]. However, in the majority of these studies, only elite cyclists were studied, with a reported annual incidence of NTCIs between 17% to 58% [10,20,31,38]. In two studies, an annual incidence of 85%[23] to 88%[39] has been reported in recreational cyclists, and this is substantially higher than the annual incidence of 2.5% in our population. This large difference may be attributed to the variation in the definition of a NTCI, the low response rates, and selection bias in studies. In our study, we defined NTCI as follows: "*Only if an injury is/was severe enough to interfere with cycling or require treatment e.g. use medication or require you to seek medical advice from a health professional*". In the other two studies the definition of NTCI was not based on whether a cyclist received medical treatment or used medication. In one of the studies, 36% of the reported NTCIs required medical attention.[23] Furthermore, we note low response rates of 13%[39] and 20.7%[23] in the two

studies respectively, resulting in possible selection bias and over-reporting of injuries. We are not aware of any studies that report the lifetime prevalence of NTCIs in recreational cyclists, and therefore we cannot compare our results to other studies. We suggest that 1) a consensus needs to be developed to standardise methods of reporting NTCIs including: definition of NTCI, exposure and severity of NTCIs and, 2) further studies to accurately determine the epidemiology (incidence and prevalence) of NTCIs is warranted.

3.7.2. Clinical characteristics of NTCIs in recreational cyclists

The main anatomical regions for NTCIs has been well studied, but mostly in elite cyclists [10,31,38]. Consistently, the main regions where NTCIs occur are the lower limb (67.9% – 82.7%), upper limb (3.8% - 10.6%), and lower back (13.4% - 15.1%).[10,31,38]. Similarly, our study also shows that the lower limb (43.4%) is most commonly affected by NTCIs but we report more NTCIs in the upper limb (19.7%), and fewer NTCIs in the lower back (11.5%) compared with those previously reported. The precise reasons for these differences are not clear, but could be related to the level and experience of cyclists in our study (recreational) compared with elite cyclists in other studies [10,31,38].

In our study, the three most affected specific anatomical sites for NTCIs were the knee (26.3%), shoulder (13.0%), and the lower back (11.5%). Specific anatomical sites for NTCIs was investigated in 11 studies, of which 5 studies were recreational cyclists and 6 in elite cyclists. Although most of these studies were done on NTCIs during multi-day cycle events, our results are very similar to the specific anatomical sites reported by recreational cyclists in these studies: knee (22.0% -53.8%), shoulder (17.0% - 30.0%), and lower back (2.7% - 41.0%).[22-23,27,39-40]. Other reports also indicate that NTCIs affecting the knee are very common and are the most likely cause of time loss due to injury in cyclists,[8,10-11,17,24,28-30,39, Clarsen, 2015 #52, Clarsen, 2010 #9,41-44]. In our study, the two most common specific NTCIs affecting the knee were PFP / AKP (14.2%) and the ITBFS (8.5%). This finding is similar to other studies where PFP / AKP was also reported as the most common NTCI.[8,10,17,20,28-31,38-39,41].

The frequency (%) of NTCIs by tissue type has only been reported in a few studies. [10,31,38]. We show that most NTCIs were soft tissue injuries (muscle, tendon, ligament

and nerve) (54.9%), and this is consistent with soft tissue NTCIs reported in other studies (ranging from 43.4% - 86.0% of NTCIs). [10,31,38]

A direct comparison between frequencies of NTCIs and types of NTCIs between these studies is limited by variation in the definitions of injuries, and differences in the populations studied (ranging from professional cyclists to multistage cycling events).

3.7.3. Severity of NTCIs in recreational cyclists

In general, the severity of NTCIs in recreational cyclists has not been well-studied and there are substantial differences in the classification and definitions of measures of severity of NTCIs. Measures of severity grading of NTCIs were investigated in six studies [10,20,23,31,38-39], of which only two were in recreational cyclists [23,39]. More severe NTCIs, broadly defined NTCIs that interfere with the cyclists ability to, and even stop them from, training or competing (Grade III and Grade IV), ranged from 5.7% - 58.8% in elite cyclists%[10,20,31,38], and 16.5% - 25.5% in recreational cyclists[23,39]. In our study, >37% of NTCIs were classified as severe enough to prevent cycling or reduce the ability to cycle, and this is higher than previous reports in recreational cyclists, but similar to elite cyclists. We also show that the main anatomical region where more severe injuries (>40% NTCIs in that region) were reported are the lower limb, head, neck and face, and the lower back and this is similar to the findings in some,[22] but not all studies[23,39]. Variation in the definition of “more severe” injuries makes comparison between study results difficult.

A novel finding in our study relates to the duration of symptoms of NTCIs. We show that almost 50% of cyclists with NTCIs reported a symptom duration >12 months, and we are aware of only two studies in recreational cyclists where symptom duration has been reported. In the one study, the duration of neurological symptoms (symptoms disappearing immediately after cycling to symptoms for >1 week) in the specific anatomical sites was reported.[39] In the other study, the mean duration of symptoms in recreational cyclists who sought medical treatment for NTCIs, was 3.7 months.[23]. We also show that the main anatomical regions where symptom duration >12 months is common are hip/groin/pelvis, head, neck and face, and the lower back. We are not aware of any studies in recreational cyclists where symptom duration by main

anatomical region has been reported. It is of concern that almost 50% of cyclists with NTCIs report a symptom duration of >12 months. We are concerned that if cyclists sought medical attention, perhaps an appropriate diagnosis was not made, or treatment was ineffective. The precise reasons for these finding are not clear, but a contributing factor is that >64% of participants were >40 years old. We recommend that further research is conducted to determine the precise reasons for the prolonged duration of symptoms, particularly focussing on NTCIs in the hip/groin/pelvis, head, neck and face, and the lower back regions.

3.8. STRENGTHS AND LIMITATIONS OF THE STUDY:

This study was a descriptive cross-sectional study, which has the advantage of obtaining a large sample size. As far as we are aware, it is the largest study describing the epidemiology and clinical characteristics of NTCIs in recreational cyclists. Our overall response rate (% of all cycle race entrants) was over 60%, which is high compared with response rates in previous similar studies. We were able to determine whether our study population was generalizable to all cycle race entrants and we note that our data shows our study population to be significantly older, and that male cyclists were significantly more represented in this group. Our results have to be interpreted with this limitation in mind. The maximum reported duration allowed for injuries was “more than 12 months” which was reported by almost half of the injured cyclists so that the distribution for duration is truncated at “more than 12 months”. Severity of injuries was only reported for 93.2% of the reported injuries. Missing data for severity was more prevalent among bone injuries compared to all other tissue type injuries (14% vs 5%, p=0.0010). We also acknowledge that due to the fact that our data are self-reported, there is a potential for recall bias. Thus, the diagnoses of injuries could not be verified by clinical assessment or special investigations. A prospective design, currently the gold standard for injury surveillance research, should be used for future studies.

3.9. SUMMARY AND CONCLUSION:

NTCIs in recreational cyclists have not been well studied. We report new information on the epidemiology, clinical characteristics and severity of NTCIs in recreational

cyclist preparing for a one-day cycling event. About 1 in 40 recreational cyclists report ever suffering from a NTCI that was severe enough to interfere with cycling or require treatment or seek medical advice from a health professional. These NTCIs affect mostly the knee, lower back and shoulder and >37% injuries are severe enough to affect training and competition. Of concern is that almost 50% of cyclists with NTCIs report a symptom duration >12 months, perhaps indicating that an appropriate diagnosis was not made, or treatment was ineffective. This is especially applicable to NTCIs of the hip / groin / pelvis, and head, neck and face and lower back. We suggest that further research should focus on determination of the risk factors associated with NTCIs in recreational cyclists in order to design and implement injury prevention programs. Education of health professionals on the appropriate diagnosis and treatment of NTCIs is also recommended.

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CHAPTER 4: PAPER 2
OLDER AGE, MORE YEARS OF TRAINING, HISTORY OF CHRONIC DISEASE AND MEDICATION USE ARE INDEPENDENT RISK FACTORS ASSOCIATED WITH NON-TRAUMATIC INJURIES IN RECREATIONAL CYCLISTS: A CROSS-SECTIONAL STUDY IN 21824 CYCLISTS - SAFER XII

4.1. ABSTRACT:

Background: Risk factors associated with non-traumatic cycling injuries (NTCIs) in recreational cyclists have not been well-studied.

Aim: To determine independent risk factors associated with NTCIs in recreational cyclists participating in a mass community-based cycling event.

Design: Cross-sectional study.

Setting: Cape Town Cycle Tour 2016

Participants: Cycle race entrants.

Methods: Of 35 914 cycle race entrants, 27 349 completed an online pre-race medical screening questionnaire, and 21 824 consenting cyclists (60.8%) were studied. Six hundred and seventeen cyclists reported a history of an NTCI. Using multi-variate analyses the following risk factors associated with NTCIs were explored: cyclist demographics (age group and gender), cycling training / racing history, history of existing chronic disease, and medication use.

Results: The prevalence ratio (PR) of NTCIs was similar in males and female cyclists, but was significantly higher in the age group >50 years compared to other age categories ($p<0.0001$). Independent risk factors associated with NTCIs (PR adjusted for gender and age) were: 1) increased average weekly training/racing (PR=1.1, $p=0.0003$), increased years of participation in distance cycling events of >2 hours (PR=1.1, $p=0.0189$) and higher average racing speed category (km/h) (PR=1.04, $p=0.0368$), 2) chronic disease history [any symptoms of CVD (PR=2.3, $p=0.0026$), any respiratory disease (PR=1.6, $p<0.0001$), any nervous system/psychiatric disease (PR=1.5, $p=0.0082$), and any GIT disease (PR=1.4, $p=0.0225$)], and 3) history of medication use [any prescribed medication use (PR=1.2, $p=0.0226$), any analgesic/anti-inflammatory medication (AAIM) use before or during racing (PR=5.1, $p<0.0001$)].

Conclusion: Older age, increased weekly training and participation in endurance cycling events, chronic disease and medication use are novel independent risk factors associated with NTCIs in recreational cyclists. Risk factors for NTCIs in recreational cyclists need to be considered when implementing injury prevention programs.

4.2. INTRODUCTION

Cycling is a popular form of transportation, recreation, fitness and sporting activity amongst people of all ages.[1-15] However, due to the nature of cycling, there is also an increased risk of acute traumatic and NTCIs amongst both amateur and professional cyclists.[1-2,4-7,11,14-16] While cycling should be encouraged as a healthy lifestyle activity because the benefits of cycling far outweigh the risk of injuries, it is important that health professionals and cyclists also take responsibility to reduce the risk of injuries.

NTCIs are defined as those injuries without a specific, identifiable event responsible for their occurrence.[17-18] About 1 in 40 recreational cyclists report ever suffering from a NTCI that was severe enough to interfere with cycling or require treatment or seek medical advice from a health professional.[19] These NTCIs affect mostly the knee, lower back and shoulder and >37% injuries are severe enough to affect training and competition.[19] Of concern is that almost 50% of cyclists with NTCIs report a symptom duration >12 months, perhaps indicating that an appropriate diagnosis was not made, or treatment was ineffective.[19] This is especially applicable to NTCIs of the hip / groin / pelvis, and head, neck and face and lower back.[19] The principles of managing NTCIs rely on establishing a detailed anatomical and pathological diagnosis of the injury and, identifying the underlying intrinsic (related to the cyclist) and extrinsic (related to the bicycle and the environment) risk factors associated with the NTCIs.[18,20-21] It is important to identify risk factors associated with NTCIs to mitigate risk of injury and develop effective injury prevention programs.[21]

There are limited studies on the risk factors for NTCIs, and most studies have only focussed on biomechanical risk factors, utilising a case-control study design.[22-24] Intrinsic risk factors that have been associated with NTCIs include older age, female gender, training load, anatomical malalignment and muscle inflexibility of the lower limb, professional bicycle fitting, muscle imbalance, lack of physical conditioning

before riding, history of prior injuries, menstrual dysfunction and psychological factors.[6,9,25-31] Similarly, suggested extrinsic risk factors for NTCIs include unsuitable training, cycling surfaces, and adult or peer pressure.[6,29-31]. However, in the majority of these studies, the identification of risk factors was limited to studies in professional cyclists, and relatively small sample sizes limiting the analyses to a uni-variate exploration for risk factors associated with NTCIs.

The aim of this study was to determine the independent risk factors associated with NTCIs in recreational cyclists participating in a mass community-based cycling event. The objectives were to explore the following specific risk factors associated with NTCIs in a large sample of recreational cyclists using a multi-variate analysis: cyclist demographics (age group and gender), cycling training / racing history, a history of existing chronic disease, and medication use.

4.3. METHODS

4.3.1. Study design and ethical considerations

This study formed part of a series of on-going SAFER (**S**trategies to reduce **A**dverse medical events **F**or the **E**xercise**R**) studies.[32] The MSc committee and the Research Ethics Committee of the Faculty of Health Sciences of the University of Pretoria approved the study (REC numbers **431/2015** and **213/2017**). Data collection for the SAFER studies is ongoing, and this study was an analysis of data collected over a one-year period (2016). A cross-sectional study design was used.

4.3.2. Participants and demographics

A total of 35 914 cyclists entered the 2016 CTCT, and 27 349 completed an online pre-race medical screening questionnaire. Of the cycle race entrants that completed the questionnaire, 21 902 gave written informed consent for their data to be used for research purposes. Of the 21 902 consenting cycle race entrants 78 cyclists had missing or incomplete data sets. Therefore, the final study population of cyclists was 21 824 (60.8% of all cycle race entrants).

Although the response rate was acceptable, a post-hoc analysis was conducted to determine if the participants in this study were indeed representative of all the cycle race entrants. Table 4.1 outlines the demographics (age group and gender) of all cyclists entering the 2016 CTCT, compared with the consenting cycle race entrants that were participants in this study.

Table 4.1: Characteristics of all cycle race entrants and cycle race entrants consenting as study participants (consenting cycle race entrants)

Characteristics		All cycle race entrants (n=35914)		Cycle race entrants consenting as study participants (n=21824)		p-value
		n	%*	n	%*	
Gender	Males	28311	78.8	17282	79.2	0.0390
	Females	7603	21.2	4542	20.8	
Age groups (years)	≤30	6453	18.0	3333	15.3	<0.0001
	31 to ≤40	7814	21.8	4447	20.4	
	41 to ≤50	10583	29.4	6382	29.2	
	>50	11064	30.8	7662	35.1	

*: % out of total

The main observation from Table 4.1 is that the study participants were significantly more in the >50 year age group (p<0.0001) as determined by the Chi-squared test,, as well as significantly more male cyclists in the study group compared with all cycle race entrants (p=0.0390) (Table 4.1).

4.3.3. Data collection

4.3.3.1. Online medical questionnaire data

All cycle race entrants from the 2016 CTCT were required to complete an online medical questionnaire at the time of registration. The main reason for this questionnaire was for medical staff to have access to medical data for care on race day. In addition, the medical data were used for risk stratification and targeted personalized educational intervention to reduce the risk of medical complications.

The online medical screening tool consisted of a series of questions developed to specifically provide clinical information for medical staff on race day. The main sections of the screening tool were based on the guidelines for cardiovascular evaluation of

middle-aged / senior individuals engaged in leisure-time sport activities (Position stand from the European Association of Cardiovascular Prevention and Rehabilitation)[33], and our previous studies in distance runners[34 35]. The online screening tool for runners was adapted to include questions specifically related to common medical complications encountered during cycling. The final screening questions related to the following: cycling training / racing history and medical history which included history of acute traumatic and NTCIs (current, or recent – last 12 months), chronic disease (CVD, risk factors for CVD, symptoms of CVD, respiratory disease, metabolic or hormonal disease, gastrointestinal disease, nervous system disease, renal or bladder disease, haematological or immune system disease, cancer, allergies, general medication use for chronic disease, and medication use before and during racing).

4.3.3.2. Selection of cyclists with NTCIs

In the medical screening tool, cyclists were asked the following specific question related to NTCIs: *"Do you or did you suffer from any symptoms of a CHRONIC (no accident) cycling injury (muscles tendons bones ligaments or joints) IN YOUR CYCLING CAREER?"*. An injury was defined as: "*An injury that is / was severe enough to interfere with cycling or require treatment e.g. use medication or require you to seek medical advice from a health professional".*

In response to a "yes" answer to this question, cyclists were grouped as having a non-traumatic (overuse) cycling injury (NTCI group = 617) and cyclists who reported no history of an NTCI (Control group = 21 207).

4.3.4. Risk factors associated with NTCIs in recreational cyclists

In this cross-sectional study, the following main categories of intrinsic risk factors associated with a past history of NTCIs were explored:

4.3.4.1. Demographics (age group and gender)

Age groups and gender were explored as possible risk factors associated with NTCIs. Cyclists were categorised in four age groups: ≤30 years, 31 to ≤40 years, 41 to ≤50 years, > 50years.

4.3.4.2. Cycling training / racing history

The following cycling training / racing history variables were investigated as possible risk factors associated with NTCIs: years of recreational cycling, years of participation in distance cycling events of >2 hours, average number of training sessions per week in the last 12 months, average weekly distance in the last 12 months, average training speed in the last 12 months, and average racing speed category.

4.3.4.3. History of chronic disease

Eleven history of chronic disease markers were included as possible risk factors associated with NTCIs: a history of existing CVD, risk factors for CVD, symptoms of CVD, respiratory disease, endocrine disease, GIT disease, nervous system or psychiatric disease, kidney or bladder disease, haematological system disease or immune system disease, cancer, and allergies.

4.3.4.4. History of medication use

Two medication types were included as possible risk factors: chronic disease prescription medication use, and use of Analgesic/anti-inflammatory medication (AAIM) (week before racing, during racing)

4.3.5. Statistical analysis

All cycle race entrant's data from the 2016 Cape Town cycle race were entered and analyses were conducted using SAS statistical software (version 9.4, Cary NC). The binary-scaled dependent variable in the model was the response to the question related to NTCIs. Cyclists were coded as having a non-traumatic (overuse) cycling injury if they reported (1) a chronic injury the past 12 months or (2) a current chronic injury or (3) a past chronic injury. Cyclist could report more than one NTCI, e.g. reporting both a neck and a shoulder injury. To qualify for coding of an injury entries for (1) how long ago the injury started, (2) which side of the body the injury was, and (3) the anatomical area should be coded. For 78 records, there were discrepancies in the coding of the relevant injury variables and these records were deleted form the data.

Since some situations arose with convergence problems, Poisson regression and (modified) Poisson regression with robust standard errors were done and included the specified independent predictor (i.e. Sex, Age). PROC GENMOD procedure with binomial distribution and log links were used. The repeated statement was included to allow for the correlated data as more than one injury could be reported by the same cyclist (exchangeable correlation structure). Prevalence ratios (PR) were calculated as the measure of association. The statistical significance level was 5%, unless specified otherwise. Univariate unadjusted prevalence ratios were reported for age and gender, cycling training / racing history, history of chronic disease, history of medication use. The multiple regression included all the univariate significant risk factors and indicated the independent risk factors for NTCIs. The multiple regression model was extended by adding the variable 'average racing speed' and was based on 18703 consenting cycle race entrant, i.e. this question had 14% missing responses and it was therefor decided to not include the variable in the first multiple model.

4.4. RESULTS

RISK FACTORS ASSOCIATED WITH NTCIS (UNIVARIATE LOGISTIC REGRESSION ANALYSIS)

4.4.1. Demographics (age group and gender)

The frequency (%) and crude unadjusted prevalence ratio (PR; with 95% confidence intervals - CI) of cyclists with a history of NTCIs by age group, and gender is depicted in Table 4.2.

Table 4.2: The frequency (n, % and 95%CI) and unadjusted prevalence ratio (PR) (with 95%CI) of cyclists with a history of NTCIs by gender and age group

Characteristics		Consenting cycle race entrants (n=21824)	Cycle race entrants with NTCIs (n=617)		PR (%, 95% CI)	p
		n	n	(%, 95% CI's)		
Gender	Males	17282	469	2.7 (2.5 - 3.0)		0.0610
	Females	4542	148	3.3 (2.8 - 3.8)	1.2 (1.0 - 1.4)	
Age groups (years)	≤30	3333	74	2.2 (1.8 - 2.8)	1.6 (1.2 - 2.1)[a]	<0.0001×
	31 to ≤40	4447	106	2.4 (2.0 - 2.9)	1.5 (1.2 - 1.9)[b]	
	41 to ≤50	6382	164	2.6 (2.2 - 3.0)	1.4 (1.1 - 1.7)[c]	
	>50	17282	273	3.6 (3.2 - 4.0)		

PR: Prevalence ratio
p: p-value
ˣ: significantly different between age group
a: >50 vs ≤30 years, p=0.0003
b: >50 vs 31 to ≤40 years, p=0.0004
c: >50 vs 41 to ≤50 years, p=0.0008

The crude unadjusted analysis showed that there was no significant difference in the prevalence ratio (PR) of NTCI between male and female cyclists (PR=1.2; p=0.0610). However, the prevalence ratio (PR) of NTCIs was significantly higher in the age group >50 years compared to the ≤30 years, 31 to <40 years, and 41 to <50 years age groups (p<0.0008).

4.4.2. Cycling training / racing history

The frequency (%) and crude unadjusted prevalence ratio (PR; with 95% confidence intervals - CI) of cyclists with a history of NTCIs, by cycling training / racing history is depicted in Table 4.3.

Table 4.3: The frequency (n, % and 95%CI) and unadjusted prevalence ratio (PR; with 95%CI) of cyclists with a history of NTCIs by cycling training / racing history

Cycling training / racing history	Points in the continuous variable#	Predicted frequency of cyclists with NTCIs at specific points in the continuous variable (%,95% CI's)	PR (%, 95% CI's)	p
Years of recreational cycling (yrs) n=21727	4yrs	2.5 (2.2 - 2.8)		<0.0001
	10yrs	2.7 (2.5 - 3.0)		
	18yrs	3.1 (2.8 - 3.3)	1.08 (1.04-1.12)*	
Years of participation in distance cycling events >2 hours (yrs) n=21727	3yrs	2.4 (2.2 - 2.6)		<0.0001
	6yrs	2.6 (2.3 - 2.8)		
	15yrs	3.2 (2.9 - 3.5)	1.13 (1.08-1.17)**	
Average weekly training / racing frequency in the last 12 months (times per week) n=21727	2 / week	2.6 (2.4 - 2.8)		<0.0001
	3 / week	2.9 (2.7 - 3.1)		
	4 / week	3.2 (2.9 - 3.5)	1.12 (1.07-1.16)***	
Average weekly cycling distance in the last 12 months (km/week) n=21727	40km	2.5 (2.3 - 2.8)		<0.0001
	80km	2.7 (2.5 - 3.0)		
	130km	3.0 (2.8 - 3.2)	1.08 (1.05-1.11)****	
Average racing speed category (km/h) n=18703##	21.1 km/h	2.5 (2.2-2.8)		<0.0001
	24.8 km/h	2.8 (2.5-3.0)		
	29.2 km/h	3.2 (2.9-3.5)	1.06 (1.03-1.09)*****	

#points on the continuous variables are the 1st quartile, median and 3rd quartile for each training variable
PR: Prevalence ratio
p: p-value
*average increase in risk for a 5 year training increase
**average increase in risk for 1 more training session per week
***average increase in risk for 40km more training per week

****average increase in risk for 2km/h increase in speed
*****average increase in risk for 2km/hr increase in speed
##variable has 14% missing responses

The crude unadjusted analysis results in Table 4.3 show that a number of training variables are associated with an increased risk of NTCIs. The highest PR of NTCIs is associated with increased years of participation in distance cycling events longer than 2 hours (PR=1.13; p<0.0001), increased average weekly training / racing frequency in the last 12 months (times per week) (PR=1.12, p<0.0001), increased average weekly cycling distance in the last 12 months (PR=1.08; p<0.0001), followed by increased years of recreational cycling (years) (PR=1.08; p<0.0001), and increased average racing speed category (PR=1.06, p<0.0001).

4.4.3. History of chronic disease

The frequency (%) and crude unadjusted prevalence ratio (PR; with 95% confidence intervals - CI) of cyclists with a history of NTCIs by history of main categories of chronic disease is depicted in Table 4.4

Table 4.4: The frequency (n, % and 95%CI) and unadjusted prevalence ratio (PR) of cyclists with a history of NTCIs by history of main category of chronic disease

History of CVD symptoms. CVD risk factors. and chronic disease		Consenting cycle race entrants× (n=21824)	Cyclists with NTCIs Cycle race entrants with NTCIs (n=617)		PR (%, 95% CI's)	p
		N	n	(%, 95% CI's)		
Any history of CVD	yes	4525	178	3.9 (3.4 - 4.5)	1.5 (1.3 - 1.8)	<0.0001
	no	17089	439	2.6 (2.3 - 2.8)		
	missing data	210	0			
Any risk factor for CVD	yes	817	38	4.7 (3.4 - 6.3)	1.7 (1.2 - 2.3)	0.0130
	no	20797	579	2.8 (2.6 - 3.0)		
	missing data	210	0			
Any symptoms of CVD	yes	233	26	11.2 (7.8 - 16.0)	4.0 (2.8 - 5.8)	<0.0001
	no	21381	591	2.8 (2.6 - 3.0)		
	missing data	210	0			
Any endocrine disease	yes	835	41	4.9 (3.6 - 6.6)	1.8 (1.3 - 2.4)	0.0050
	no	20784	573	2.8 (2.5 - 3.0)		
	missing data	205	3			
Any respiratory disease	yes	2482	135	5.4 (4.6 - 6.4)	2.2 (1.8 - 2.6)	<0.0001
	no	19157	482	2.5 (2.3 - 2.7)		
	missing data	185	0			
Any GIT disease	yes	1169	70	6.0 (4.8 - 7.5)	2.3 (1.8 - 2.9)	<0.0001
	no	20456	543	2.7 (2.4 - 2.9)		
	missing data	199	4			

History of CVD symptoms. CVD risk factors. and chronic disease		Consenting cycle race entrants× (n=21824)	Cyclists with NTCIs Cycle race entrants with NTCIs (n=617)		PR (%, 95% CI's)	p
		N	n	(%, 95% CI's)		
Any nervous system / psychiatric disease	yes	767	58	7.6 (5.9 - 9.7)	2.8 (2.2 - 3.7)	<0.0001
	no	20864	557	2.7 (2.5 - 2.9)		
	missing data	193	2			
Any kidney or bladder disease	yes	645	38	5.9 (4.3 - 8.0)	2.1 (1.6 - 2.9)	0.0009
	no	20990	578	2.8 (2.5 - 3.0)		
	missing data	189	1			
Any haematological or immune disease	yes	293	15	5.1 (3.1 - 8.4)	1.8 (1.1 - 3.0)	0.0760
	no	21325	600	2.8 (2.6 - 3.0)		
	missing data	206	2			
Any cancer	yes	701	28	4.0 (2.8 - 5.7)	1.4 (1.0 - 2.1)	0.1130
	no	20926	587	2.8 (2.6 - 3.0)		
	missing data	197	2			
Any allergies	yes	2968	133	4.5 (3.8 - 5.3)	1.7 (1.4 - 2.1)	<0.0001
	no	18659	482	2.6 (2.4 - 2.8)		
	missing data	197	2			

CVD: Cardiovascular disease
GIT: Gastrointestinal tract
n: number of cyclists in the study
PR: Prevalence ratio
p: p-value

The main observation from Table 4.4 is that a history of chronic disease is associated with a higher risk of NTCIs. Specifically, the crude unadjusted analysis showed that the highest PR of NTCIs is associated with any symptoms of CVD (PR=4.0; p<0.0001), followed by any risk factor for CVD (PR=1.7; p=0.0130), and any history of CVD (PR=1.5; p<0.0001). In addition, any nervous system / psychiatric disease (PR=2.8; p<0.0001), any GIT disease (PR=2.3; p<0.0001), any respiratory disease (PR=2.2; p<0.0001), any kidney or bladder disease (PR=2.1; p=0.0009), any endocrine disease (PR=1.8; p=0.0050), and any allergies (PR=1.7; p<0.0001) were also associated with a higher risk of NTCIs.

4.4.4. History of medication use

The frequency (%) and crude unadjusted prevalence ratio (PR; with 95% confidence intervals - CI) of cyclists with a history of NTCIs by regular use of any prescription medications, and medication use during training and racing is depicted in Table 4.5.

Table 4.5: The frequency (n, % and 95%CI) and prevalence ratio (PR) of cyclists with a history of NTCIs by history of regular use of any medications, and use of medication during training and racing

History of medication use		Consenting cycle race entrants× (n=21824)	Cycle race entrants with NTCIs (n=617)		PR (%, 95% CI's)	p
		n	n	(%, 95% CI's)		
Any regular prescribed medication use for chronic disease	yes	5505	229	4.2 (3.7 - 4.7)	1.7 (1.5 - 2.0)	0.0001
	no	16126	388	2.4 (2.2 - 2.7)		
	missing data	193	0			
Any analgesic/anti-inflammatory medication (AAIM) use in the week before or during racing	yes	1892	231	12.2 (10.8 - 13.8)	6.3 (5.4 -7.3)	0.0001
	no	19658	383	1.9 (1.8 - 2.2)		
	missing data	274	3			

n: number of cyclists in the study
PR: Prevalence ratio
p: p-value

Cyclists with a history of any regular prescribed medication use for chronic disease had a significantly higher PR of NTCIs compared to cyclist not using any prescribed medications for chronic disease (PR=1.7; p<0.0001). In addition, cyclists reporting use of any AAIM in the week before or during racing had a significantly higher PR of NTCIs compared to cyclists not using any AAIM in the week before or during racing (PR=6.3, p<0.0001).

RISK FACTORS ASSOCIATED WITH NTCIS (MULTIPLE REGRESSION ANALYSIS)

The multiple regression included all the univariate significant risk factors and indicated the independent risk factors for NTCIs. The frequency (%) and adjusted prevalence ratio (PR; with 95% confidence intervals - CI) of cyclists with a history of NTCIs by main categories of training load, history of chronic disease or medications use, and injuries is depicted in Table 4.6.

Table 4.6: The adjusted* frequency (%; with 95%CI) and prevalence ratio (PR; with 95%CI) of cyclists with NTCIs by combined main categories of risk factors (history, illness, symptoms, medications use and injuries)

			Cyclists with NTIs (%, 95% CI's)	PR (%, 95% CI's)	p
Cycling training / racing history	Years of participation in distance cycling events >2 hours	3yrs	7.0 (4.7 - 10.4)	1.1 (1.0 - 1.1)	0.0189
		6yrs	7.2 (4.8 - 10.9)		
		15yrs	8.1 (5.2 - 12.6)		
	Average weekly training / racing frequency in the last 12 months (times per week)	2 / week	8.1 (5.5 - 11.8)	1.1 (1.0-1.1)	0.0003
		3 / week)	8.8 (6.0 - 12.9)		
		4 / week)	9.6 (6.5 - 14.2)		
History of chronic disease	Any symptoms of CVD	yes	16.9 (11.6 - 24.5)	2.3 (1.6 -3.3)	0.0026
		no	7.5 (6.4 - 8.7)		
	Any respiratory disease	yes	14.1 (11.1 - 18.0)	1.6 (1.3 -1.9)	<0.0001
		no	8.9 (7.1 - 11.3)		
	Any GIT disease	yes	13.2 (10.0 - 17.5)	1.4 (1.1 - 1.8)	0.0225
		no	9.6 (7.7 - 11.8)		
	Any nervous system / psychiatric disease	yes	13.9 (10.4 - 18.6)	1.5 (1.2 - 2.0)	0.0082
		no	9.1 (7.3 - 11.2)		
History of medication use	Any regular prescribed medication use for chronic disease	yes	12.5 (10.0 - 15.6)	1.2 (1.0 - 1.5)	0.0226
		no	10.1 (7.9 - 12.9)		
	Any AAIM use in the week before or during racing	yes	25.3 (20.4 - 31.5)	5.1 (4.3 - 6.0)	<0.0001
		no	5.0 (3.9 - 6.4)		

AAIM: analgesic/anti-inflammatory medication
CVD: Cardiovascular disease
GIT: Gastrointestinal tract
PR: Prevalence ratio
p: p-value
*: Adjusted for gender and age group

In the adjusted analysis (adjusted for gender and age group), the first main observation was that the independent training related risk factors associated with a higher PR of NTCIs were: increased average weekly training / racing frequency in the last 12 months (times per week) (PR=1.1, p=0.0003), increased years of participation in distance cycling events of >2 hours (PR=1.1, p=0.0189). Secondly, NTCIs were associated with a history of chronic disease as follows: any symptoms of CVD (PR=2.3, p=0.0026), any respiratory disease (PR=1.6, p<0.0001), any nervous system / psychiatric disease (PR=1.5, p=0.0082), and any GIT disease (PR=1.4, p=0.0225). Finally, a history of medication use was significantly associated with increased risk of NTCIs as follows: any AAIM used in the week before or during racing (PR=5.1, p<0.0001), and any regular prescribed medication use for chronic disease (PR=1.2, p=0.0226).

The estimates in Table 4.6 were based on the total consenting cycle race entrants of 21824. The final model was extended by adding the variable 'average racing speed' with 18703 responses for the consenting cycle race entrant. The results of the extended model show that 'the number of years participating in distance cycling events' and 'speed' both contribute the same information to the model. Including only one in the model, i.e. speed, show that it is an independent training related risk factor associated with a higher PR of NTCIs [PR=1.04 (1.00 – 1.07), p=0.0368].

4.5. DISCUSSION

The first finding of this study is that the prevalence ratio (PR) of NTCIs was not significantly different between males and female cyclists, but was higher in the age group >50 years compared to other age groups (p<0.0001). The main novel finding of this study is that the following independent risk factors are associated with NTCIs: 1) training related [increased average weekly training/racing frequency (PR=1.1, p=0.0003), increased years of participation in distance cycling events >2 hours (PR=1.1, p=0.0189), higher average racing speed category (km/h) (PR=1.04, p=0.0368)], 2) a history of chronic disease [any symptoms of CVD (PR=2.3, p=0.0026), any respiratory disease (PR=1.6, p<0.0001), any nervous system / psychiatric disease (PR=1.5, p=0.0082), and any GIT disease (PR=1.4, p=0.0225)], and 3) a history of any AAIM used in the week before or during racing (PR=5.1, p<0.0001) and any regular prescribed medication use for chronic disease (PR=1.2, p=0.0226)].

Factors associated with NTCIs has been explored in previous studies using a univariable analysis approach.[9,25-28] There are limited number of studies that have explored the relationship between multiple risk factors associated with NTCIs and it is difficult to compare our results to the results of these studies, because of the methodological differences. The common methodological differences between studies include: differences in the definition of injury[9,25-27], variability on definitions of NTCI and reporting the exposure (e.g. reporting the factors associated with NTCI during multi-day staged races)[26,28], small sample sizes not allowing for multi-variable analysis[9,25,28], low-response rates with possible selection bias[25,27], and the use of self-reported data with differences in timing and content of questionnaire administration[9,25-28]. We note

that multivariable analysis was only performed in two studies to identify independent risk factors.[9,25] Most studies utilized univariable analysis,[26-28] and interaction between risk factors could not be explored.

In two studies it has been suggested that younger age is a risk for development of medial knee pain, back, buttocks, and upper leg complaints in cyclists.[26,28] while in another study, older age was identified as a risk factor for seeking medical care for a cycling injury.[9] However, in one study, no statistical association between age and cycling injury was found.[27] The results from our study, show that the prevalence ratio (PR) of NTCIs was higher in the age category >50 years compared to other age categories ($p<0.0001$). We did not explore age as a risk factor for NTCIs at specific anatomical sites in cyclists. In one prospective observational study where multivariable analysis was conducted, the main findings were that pain level (at enrolment) and older age were associated with injuries in cyclists.[9] To extrapolate these findings to our study on NTCIs is not possible, because of the differences in the definition of injury. In particular, no distinction was made between traumatic injuries and NTCIs in this study.[9]

It has been suggested that female cyclists have an increased risk for developing NTCIs, particularly in the neck (1.5 times) and shoulder (2.2 times), and the medial knee.[25,27-28] However, in two studies, no significant differences in injury risk at various anatomical sites was found between male and female cyclists.[25,28] Similarly, our study, also reported that the PR of NTCIs was not significantly different between males and female cyclists.

There is some evidence that increased weekly training and increased racing frequency is associated with the development of NTCIs.[25] In a cross-sectional study, it was found that participants were 2.3 to 4 times more likely to be treated for an overuse injury during the tour if they usually bicycled less than 26 miles (41,8 km) per week in preparation for the tour.[26]. In our study, we show that increased average weekly training/racing frequency ($PR=1.1$, $p=0.0003$) is an independent risk factor for NTCIs in recreational cyclists. It has been suggested that cyclists with less years of cycling experience had more buttock and groin complaints.[25,28] However, in one study, no relationship was evident between long distance riding experience and any other

NTCIs.[28] Our finding of increased years of participation in distance cycling events as an independent risk factor for NTCIs differs from other studies. The possible reasons for this is not clear. However, in our study, because of our large sample size, we could use a multivariate analysis to asses for independent risk factors. In the two studies that we could compare our results to, one study only utilized univariate analysis [26], and for the other study, results were only adjusted for gender[25]. A further independent risk factor for NTCIs in our study was higher average race cycling speed. This is in contrast to a study using univariate analysis, where a slower race cycling speed was associated with a 1.9 to 3.5 times more likely chance to be treated for an overuse injury during the tour if they usually rode at less than 14 miles per hour (22.5 km/h).[26]

As far as we are aware, the association between underlying chronic disease and NTCIs in recreational cyclists has not been explored. However, underlying chronic disease (hypertension, heart disease, diabetes, asthma, cardiac arrhythmia, malignancies) has been reported in recreational cyclists, with a prevalence of chronic disease that varies between 10% - 16%.[25,28] We show that a history of chronic disease [any symptoms of CVD (PR=2.3, p=0.0026), any respiratory disease (PR=1.6, p<0.0001), any nervous system / psychiatric disease (PR=1.5, p=0.0082), and any GIT disease (PR=1.4, p=0.0225)] is an independent risk factor associated with NTCIs. We also show that any regular prescribed medication use for chronic disease is an independent risk factor associated with NTCIs in recreational cyclists (PR=1.2, p=0.0226)]. Due to the nature of our cross-sectional design, we cannot establish a cause-effect relationship between NTCI and chronic disease, and this study was also not designed to determine the mechanism/s for the relationship between chronic disease and risk of NTCIs. This requires further study.

Finally, a history of AAIM medication use in the week before or during racing is strongly associated with NTCIs in recreational cyclists (PR=5.1, p<0.0001). As far as we are aware, the association between AAIM medication use and NTCIs in recreational cyclists has not been explored in previous studies. This finding is not surprising, and is likely to be related to the use of AAIM to treat the symptoms of NTCI before and during races. We have shown that NTCIs in recreational cyclists frequently have a symptom duration > 12 months[19], and it is therefore likely that cyclists with NTCIs use AAIM to treat symptoms during cycling. AAIM have been associated with possible

medical complications during endurance exercise[35] and we suggest that further studies are conducted to determine the prevalence of AAIM use in cyclists, as well as the risk of medical complications associated with AAIM during cycling.

4.6. STRENGTHS AND LIMITATIONS OF THE STUDY

The main strengths of this study are the large sample size (n=21824), a high overall response rate (as a % of all cycle race entrants = 60%), and our post-hoc analysis to determine if our sample was representative of all cycle race entrants. We were able to determine if our study population was generalizable to all cycle race entrants and we note that our data shows that our study population was significantly older, and that male cyclists were significantly more represented in this group. Most significantly, because of our large sample size, we were able to do a multivariate analysis. To our knowledge, this is also the first study investigating underlying chronic disease, medication use and a history of a NTCIs as independent risk factors associated with NTCIs in recreational cycling. Specific limitations of our study were that our data are self-reported, and there is a potential for recall bias. We acknowledge that, from our results, we cannot infer cause-effect as this was a cross-sectional study design. We suggest that further research be aimed at determining the cause-effect relationship between NTCIs and specific chronic diseases or medications. We also acknowledge that we did not explore all possible risk factors associated with NTCIs, including specific anatomical sites of NTCIs.

4.7. SUMMARY AND CONCLUSION:

Risk factors associated with NTCIs in recreational cyclists have not been well-studied. In our study, we identified novel independent risk factors associated with a history of NTCIs, using a multi-variate model on a large sample of recreational cyclists entering for a one-day cycling event. Our data show an association between NTCIs and cycling training / racing history [increased years of participation in distance cycling events > 2 hours, and increased average weekly training / racing frequency in the last 12 months (times per week)], a history of chronic disease [any symptoms of CVD, any respiratory disease, any GIT disease, and any nervous system / psychiatric disease], and a history of medication use [any regular prescribed medication use for chronic disease, and any AAIM used in the week before or during racing]. These findings are important

for clinicians who consult with cyclists presenting with NTCIs. Clinicians should consider that NTCIs are not associated with a single aetiology, but rather a more complex interaction of a variety of intrinsic and extrinsic factors requiring careful and systematic clinical assessment. We suggest that clinicians explore the possibility that NTCIs may, in some cases, be associated with underlying chronic disease and / or side effects of medications that are used by these individuals. Finally, we acknowledge that future research is required to determine the cause-effect relationship between NTCIs and the factors we identified, and also explore possible pathophysiological mechanisms that may link NTCIs to underlying chronic disease and medication use. This includes investigating more complex (direct and indirect) relationships between intrinsic and extrinsic factors and NTCIs.

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CHAPTER 5: FINDINGS, LIMITATIONS, STRENGTHS, CONCLUSION AND RECOMMENDATIONS

The aim of this study was to describe the epidemiology, clinical characteristics and severity of NTCIs, and determine the independent risk factors associated with NTCIs in recreational cyclists that registered for the CTCT.

5.1. PRIMARY FINDINGS

The primary findings are as follows:

1) Recreational cyclists reported a lifetime prevalence of NTCIs of 2.8% (2.6 – 3.1) (about 1 in 35 cyclists), with an annual incidence of 2.5%. the point prevalence?
2) The prevalence ratio (PR) of NTCIs was not significantly different between males and female cyclists, but was higher in the age group >50 years compared to other age groups ($p<0.0001$).
3) The lower limb was the most common main anatomical region affected by NTCIs (43.4%), followed by the upper limb (19.7%), lower back (11.5%), and hip / groin / pelvis (10.7%).
4) The three most affected specific anatomical sites of NTCIs were the knee (26.3%), shoulder (13.0%), and the lower back (11.5%), and the most common specific NTCIs was PFP / AKP (14.2%).
5) Of the reported NTCIs, 55% were soft tissue injuries (muscle, tendon, ligament and nerve).
6) Almost 50% of cyclists with an NTCI reported a symptom duration of more than12 months.
7) Almost 60% of hip / groin / pelvis, head, neck and face, and lower back NTCIs were reported as having a symptom duration of greater than12 months.
8) More than 37% of NTCIs were severe enough to reduce or prevent cycling (Grades III and IV).
9) More severe NTCIs occurred mainly (>40%) in the lower limbs, head, neck and face, and the lower back.

The main novel findings in this study are that the following independent risk factors associated with NTCIs were identified:

1) Cycling training / racing history as independent risk factors associated with NTCIs
    a. increased average weekly training/racing frequency (PR=1.1, p=0.0003),
    b. increased years of participation in distance cycling events >2 hours (PR=1.1, p=0.0189),
    c. higher average racing speed category (km/h) (PR=1.0, p=0.0368).
2) A history of chronic disease as independent risk factors associated with NTCIs
    a. any symptoms of CVD (PR=2.3, p=0.0026),
    b. any respiratory disease (PR=1.6, p<0.0001),
    c. any nervous system / psychiatric disease (PR=1.5, p=0.0082), and
    d. any GIT disease (PR=1.4, p=0.0225).
3) History of medication use as independent risk factors associated with NTCIs
    a. A history of any AAIM used in the week before or during racing (PR=5.1, p<0.0001) and
    b. any regular prescribed medication use for chronic disease (PR=1.2, p=0.0226).

5.2. LIMITATIONS

The data from this research are self-reported, there is a potential for recall bias, diagnoses of injuries could not be verified by clinical assessment or special investigations, and from the results, cause-effect cannot be inferred, as this was a cross-sectional study design. The maximum reported duration allowed for injuries was “more than 12 months” which was reported by almost half of the injured cyclists so that the distribution for duration is truncated at “more than 12 months”. Severity of injuries was only reported for 93.2% of the reported injuries. Missing data for severity was more prevalent among bone injuries compared to all other tissue type injuries (14% vs 5%, p=0.0010). The researcher also acknowledges that not all possible risk

factors associated with NTCIs, including specific anatomical sites of NTCIs, were explored.

5.3. STRENGTHS

This study was a descriptive cross-sectional study, which has the advantage of obtaining a large sample size. As far as the researcher is aware, it is the largest study describing the epidemiology and clinical characteristics of NTCIs in recreational cyclists. The overall response rate (as a % of all cycle race entrants) was over 60%, which is high compared with response rates in previous similar studies. With a post-hoc analysis, the researcher was able to determine that the study population was, with some limitations, generalizable to all cycle race entrants.. Most significantly, because of the large sample size, the researcher was able conduct a multivariate analysis. To the researchers' knowledge, this is also the first study investigating underlying chronic disease, medication use and a history of NTCIs as independent risk factors associated with NTCIs in recreational cycling.

5.4. CONCLUSION

NTCIs in recreational cyclists have not been well studied. The researcher reports new information on the epidemiology, clinical characteristics and severity of NTCIs in recreational cyclist preparing for a one-day cycling event. About 1 in 40 recreational cyclists report ever suffering from a NTCI that was severe enough to interfere with cycling, require treatment or seek medical advice from a health professional. These NTCIs affect mostly the knee, lower back and shoulder and more than 37% of the injuries were severe enough to affect training and competition.

Risk factors associated with NTCIs in recreational cyclists have also not been well-studied. In this study, the researcher identified novel independent risk factors associated with a history of NTCIs, using a multi-variate model on a large sample of recreational cyclists entering a one-day cycling event. The data shows an association between NTCIs and cycling training / racing history [increased years of participation in distance cycling events >2 hours, and increased average weekly training / racing frequency in the last 12 months (times per week)], a history of chronic disease [any symptoms of CVD, any respiratory disease, any GIT disease, and any nervous system

/ psychiatric disease], and a history of medication use [any regular prescribed medication use for chronic disease, and any AAIM used in the week before or during racing].

5.5. RECOMMENDATIONS

It is recommended that, of the identified independent risk factors associated with NTCIs, further research should focus on developing and implementing preventative strategies. Of concern is that almost 50% of cyclists with NTCIs report a symptom duration >12 months, perhaps indicating that an appropriate diagnosis was not made, or treatment was ineffective. This is especially applicable to NTCIs of the hip / groin / pelvis, and head, neck and face and lower back. Education of health professionals on the appropriate diagnosis and treatment of NTCIs is also recommended. A prospective design, currently the gold standard for injury surveillance research, should be used for future studies.

The findings of this research are important for clinicians who consult with cyclists presenting with NTCIs. Clinicians should consider that NTCIs are not associated with a single aetiology, but rather a more complex interaction of a variety of intrinsic and extrinsic factors requiring careful and systematic clinical assessment. It is recommended that clinicians explore the possibility that NTCIs may, in some cases, be associated with underlying chronic disease and / or side effects of medications that are used by these individuals. Finally, the researcher acknowledges that future research is required to determine the cause-effect relationship between NTCIs and the factors identified in this research, and also explore possible pathophysiological mechanisms that may link NTCIs to underlying chronic disease and medication use. This includes investigating more complex (direct and indirect) relationships between intrinsic and extrinsic factors and NTCIs.

APPENDIX A: ETHICS APPROVAL CERTIFICATE

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.
+ FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
+ IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee

29/06/2017

Approval Certificate
New Application

Ethics Reference No.: 213/2017

Title: The epidemiology of non-traumatic injuries in road cyclists participating in the Cape Town Cycle Tour

Dear Mr Francois du Toit

The **New Application** as supported by documents specified in your cover letter dated 7/06/2017 for your research received on the 7/06/2017, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 28/06/2017.

Please note the following about your ethics approval:

- Ethics Approval is valid for 2 years
- Please remember to use your protocol number (**213/2017**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:

- The ethics approval is conditional on the receipt of **6 monthly written Progress Reports**, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

*** Kindly collect your original signed approval certificate from our offices, Faculty of Health Sciences, Research Ethics Committee, Tswelopele Building, Room 4.59 / 4.60.*

Dr R Sommers; MBChB; MMed (Int); MPharMed,PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 46 and 48. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2016 (Department of Health).

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APPENDIX B: DATA RECORDING FORMS / DOCUMENTS SENT TO PARTICIPANTS

PRE-RACE MEDICAL QUESTIONNAIRES

CAPE TOWN CYCLE TOUR

Information preceding the medical questionnaire

Dear Cyclist,

Medical information required during race entry process

The Cape Town Cycle Tour Medical Team treats more than 2400 cyclists who receive medical care at the medical facilities – both on the route, as well as at the medical tent at the finish. By reviewing the injuries and illnesses we were able to adequately plan for the 2015 year.

We would like to focus on further preventing as many medical events as possible in order to make this the safest race on the cycling calendar!

The Medical Team in conjunction with the event organisers decided to make this medical questionnaire a part of the registration process for 2016. The questionnaire is therefore included in the online registration process for completion by all cyclists.

The medical questionnaire consists of a series of yes/no questions relating to your medical history, previous medical complications during races or training and common injuries. If you are healthy and have no injuries, it will take approximately 5 minutes to complete (a bit longer if there are medical details you need to enter). In the interests of your health and safety, the medical team may contact you before or after the race for further information about any medical conditions or injuries you may have.

Please take the necessary time and care to complete this section of the entry form as accurately as possible. In addition, at the end of this questionnaire, we will also ask you to consider that the medical information be used for on-going medical research so that we can continue with our effort to improve medical care and race safety.

Medical Team

Page 1 questions (all compulsory fields)
Please note that we require you to provide answers to all the questions

General cycling and training information

For how many years have you been a recreational cyclist* (Please select from the dropdown box)		years
For how many years have you participated in distance cycling events > 2 hours?* (Please select from the dropdown box)		years
In the last 12 months, on average, how many times a week do you cycle (train and race) (Please select from the dropdown box)?*		per week
In the last 12 months, what is your average weekly cycling distance in km?* (Please select from the dropdown box)		km/week
In the last 12 months, what is your average training speed? (Please select from the dropdown boxes – km box and hour box) *		km/hour
What is your current body weight (mass) to the nearest KILOGRAM?*		kg
What is your height in CENTIMETRES?*		cm

Page 2 questions (all compulsory fields)

General cycling training information

In the past 12 months, please indicate the average percentage time that you cycle on a stationary bicycle/wind trainer/watt bike?		% time on stationary bike/trainer
In the past 12 months, please indicate the average percentage time that you spent cycling on roads (tar/concrete/brick)?		% time on roads
In the past 12 months, please indicate the average percentage time that you do trail/mountain biking on gravel roads (e.g. jeep tracks)?		% time MTB on gravel roads
In the past 12 months, please indicate the average percentage time that you do trail/mountain biking on footpaths/single tracks?		% time MTB on footpaths / single tracks

Page 3 questions (yes/no compulsory)

Medical information

- **You will now be guided through a series of 17 questions that relate to your medical history**
- **The questions are mostly in a yes/no format and should take you only a few minutes to complete, unless you have medical conditions in which case you will be directed to provide more information**
- **Please read these questions carefully and complete the information as accurately as possible**
- **Please note that this information is vital for your safety on race day and for our planning of the medical care**
- **The information is NOT intended to prevent you from taking part on race day**
- **Please be as accurate and comprehensive as you can in providing this information**

Are you aware or have you ever been diagnosed with any risk factors for heart or blood vessel disease, including high blood cholesterol, a family member with heart disease, cigarette smoking, lack of physical activity, high blood pressure, being overweight or having diabetes mellitus (Blood sugar sickness)?

○ Yes

- ○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Please tick the appropriate condition/s that you suffer/ed from
You may tick more than one box if needed

- ☐ High blood pressure
- ☐ High blood cholesterol
- ☐ Cigarette smoking
- ☐ Obesity (overweight)
- ☐ Diabetes mellitus (Blood sugar sickness)
- ☐ Family history of heart disease (< 50 years)

Page 4 questions (yes/no compulsory)
Have you ever suffered from any heart or blood vessel conditions, including heart attack, undiagnosed chest pain, coronary artery bypass operation (surgery to improve blood flow to the heart), angioplasty (widening of narrowed vessels)(balloon), heart failure, heart transplant, cardiac arrhythmia (abnormal heart beat), rheumatic fever (inflammatory disease that can involve the heart, joints, skin and brain), heart murmur, cardiomyopathy (heart muscle disease causing breathlessness and swelling of the legs), myocarditis (inflammation of the heart muscle), use of a pacemaker or inherited heart defect?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Please tick the appropriate condition/s that you suffer/ed from (you may tick more than one box if needed)

- ☐ Myocardial infarction (heart attack)
- ☐ Chest pain that has been diagnosed as "angina"
- ☐ Coronary artery bypass graft (CABG) (surgery to improve blood flow to the heart).
- ☐ Angioplasty (no stent) (widening of narrowed vessels)
- ☐ Angioplasty (with stent) (widening of narrowed vessels)
- ☐ Heart failure
- ☐ Heart transplant
- ☐ Arrhythmia (abnormal heart beat)
- ☐ Rheumatic fever (inflammatory disease that can involve the heart, joints, skin and brain)
- ☐ Heart murmur
- ☐ Cardiomyopathy (heart muscle disease causing breathlessness and swelling of the legs)

- [ ] Myocarditis (inflammation of the heart muscle)
- [ ] Use of a pacemaker
- [ ] Inherited conditions of the heart or blood vessels
- [ ] Any other form of heart or blood vessel disease (please specify)

Page 5 questions (yes/no compulsory)

Do you currently suffer from any symptoms of heart or blood vessel disease including swollen ankles, abnormal shortness of breath (with exercise), chronic dry cough, palpitations, chest pain, pain (or discomfort) in the neck, jaw, or arms at rest or during exercise, dizziness, fainting spells, and/or calf pain when cycling/running/walking/swimming?

- ○ Yes
- ○ No

If no response, go to next page

If yes response, then drop down the following box on same page (compulsory to select at least one)

Please tick the appropriate condition/s that you suffer/ed from (you may tick more than one box if needed)

- [ ] Swollen ankles
- [ ] Water retention
- [ ] Shortness of breath when sitting or lying down
- [ ] Shortness of breath with mild exercise
- [ ] Waking up with shortness of breath at night
- [ ] Palpitations with no dizziness
- [ ] Palpitations that make you dizzy
- [ ] Chest pain when sitting
- [ ] Chest pain when performing exercise
- [ ] Chest pain when you are emotionally stressed
- [ ] Pain (or discomfort) in the neck, jaw, arms at rest or during exercise
- [ ] Dizziness during exercise
- [ ] Fainting spells
- [ ] Chronic dry cough
- [ ] Painful calves when walking

Page 6 questions (yes/no compulsory)

Have you ever collapsed (fell down-NOT because of an accident) needing medical attention during, at the finish or after a race or training session?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following questions on the same page (compulsory to select / complete fields)
Have you ever collapsed during training or racing?

- ○ Training
- ○ Racing
- ○ Training and racing

How many times have you collapsed in training session or races during the last five years?

Races: _____

Training session: _____

How many times have you collapsed in training session or races during the last 12 months (1 year)?

_____

When you collapse, does it mostly occur before or after the finish line / completion of the training session?

- ○ Before the finish
- ○ After the finish

What is the cause of your collapse?

- ☐ Dehydration
- ☐ Heat illness
- ☐ Hyponatraemia(low salt levels confirmed by a blood test)
- ☐ Low blood pressure
- ☐ Low blood sugar
- ☐ Other condition, please specify _____

Have you ever been ill enough during a race to require an intravenous (IV) drip?

- **YES**
- **NO**

Page 7 questions (yes/no compulsory)
Have you ever in your cycling career suffered from muscle cramping (painful, spontaneous, sustained spasm of a muscle) during or immediately (within 6 hours) after cycling (in training or competition)?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following questions on the same page (compulsory to select / complete fields) – may need to split over two pages as there are a number of questions
For how many years have you suffered from cramping?

Did you suffer from cramping during or after cycling in the last 12 months?

- Yes
- No

In the last 10 races or training sessions, how many times have you experienced cramping?

Races /10:

Training sessions /10:

What treatment/s have you had that successfully relieved an acute cramp?
You can tick more than one

- Stretching
- Resting
- Drinking fluid
- Ice application
- Massage
- Magnesium
- Salt (tablets or solution)
- Pickle juice in your mouth
- Other, please specify

At what point in the race or training session do you usually first experience cramping?

- First quarter
- Second quarter
- Third quarter
- Fourth quarter
- After the race
- No pattern
- Other, please specify

In which muscle do you usually cramp?
Please tick the muscle in which cramps most frequently occur

- Calves
- Hamstrings
- Quadriceps (thigh)
- Foot muscles

☐ Other, please specify

Have you ever suffered from cramping in your whole body (arms and legs)?

○ Yes

○ No

Have you ever been admitted to hospital following cramping?

○ Yes

○ No

Have you ever been confused or in a coma during or after a cramping episode?

○ Yes

○ No

Have you ever had "dark urine" in the 3 days following a cramping episode?

○ Yes

○ No

If you cramp, how severe is the cramp usually?
Please tick one box

○ Mild: < 5 minutes and you are able to continue exercising

○ Moderate: 5-15 minutes and you are able to continue exercising

○ Severe: >15 minutes or if you have to STOP exercising

Page 8 questions (yes/no compulsory)
Do you currently suffer from any metabolic or hormonal disease including diabetes mellitus, thyroid gland disorders, hypoglycaemia (low blood sugar), hyperglycaemia (high blood sugar), or heat intolerance?

○ Yes

○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Please tick the appropriate condition/s that you suffer/ed from
You may tick more than one box if needed

☐ Hyperglycaemia (high blood sugar) (Pre-diabetes)

☐ Type 1: Insulin dependent (Diabetes Mellitus)

☐ Type 2: Non insulin dependent (Diabetes Mellitus)

☐ Underactive thyroid (hypothyroidism)

☐ Overactive thyroid (hyperthyroidism)

☐ Hypoglycaemia (low blood sugar)

☐ Heat intolerance

Page 9 questions (yes/no compulsory)

Do you suffer from any respiratory (lung) disease including asthma, emphysema (COPD – chronic obstructive pulmonary disease), wheezing, cough, postnasal drip, hay fever, or repeated flu like illness?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)

Please tick the appropriate condition/s that you suffer/ed from
You may tick more than one box if needed

- ☐ Asthma (Non exercise-induced)
- ☐ Asthma (Exercise-induced)
- ☐ Wheezing during exercise
- ☐ Cough during exercise
- ☐ Post nasal drip
- ☐ Allergies/hay fever (ear, nose, throat)
- ☐ Repeated infections in the respiratory tract (> 3 per year)
- ☐ Previous lung complaints
- ☐ COPD (Chronic obstructive pulmonary disease)
- ☐ Interstitial lung disease (e.g. Pneumonia, Pulmonary fibrosis, Asbestosis, Sarcoidosis - affects lungs and lymph glands)
- ☐ Cystic fibrosis (thick accumulation of mucus in lungs, pancreas and other organs)
- ☐ Other respiratory complaints

Page 10 questions (yes/no compulsory)

Do you suffer from any gastrointestinal disease (Irritable bowel syndrome, spastic colon, indigestion, constipation, heartburn, nausea, vomiting, abdominal pain, weight loss or gain (> 5kg), a change in bowel habits, chronic diarrhoea, blood in the stools) or past history of liver or gallbladder disease?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)

Please tick the appropriate condition/s that you suffer/ed from
You may tick more than one box if needed

- ☐ Heartburn
- ☐ Nausea/vomiting
- ☐ Abdominal pain
- ☐ Weight loss (>5kg) in the last 2 years

- [ ] Weight gain (>5kg) in the last 2 years
- [ ] A change in bowel habits over the last year
- [ ] Chronic diarrhoea
- [ ] Blood in stool
- [ ] Abdominal complaints during exercise
- [ ] Liver/gallbladder disease
- [ ] Other gastrointestinal complaints

Page 11 questions (yes/no compulsory)

Do you suffer from any diseases of the nervous system including past history of stroke or transient ischaemic attack (TIA or "mini stroke"), frequent headaches, epilepsy, depression, anxiety attacks, muscle weakness, nerve tingling, loss of sensation, or chronic fatigue?

- ○ Yes
- ○ No

If no response, go to next page

If yes response, then drop down the following box on same page (compulsory to select at least one)

Please tick the appropriate condition/s that you suffer/ed from

You may tick more than one box if needed

- [ ] Stroke or transient ischaemic attack ("mini" stroke)
- [ ] Frequent headaches
- [ ] Epilepsy
- [ ] Depression
- [ ] Anxiety attacks
- [ ] Other psychological/psychiatric conditions
- [ ] Muscle weakness
- [ ] Nerve tingling/loss of sensation
- [ ] Chronic fatigue
- [ ] Other nervous system complaints

Page 12 questions (yes/no compulsory)

Do you suffer from any disease of the kidney or bladder including past history of kidney or bladder disease, blood in the urine, loin pain, kidney stones, frequent urination, or burning during urination?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Please tick the appropriate condition/s that you suffer/ed from
You may tick more than one box if needed

- ☐ Past history of kidney disease
- ☐ Past history of bladder disease
- ☐ History of blood in the urine
- ☐ Chronic loin pain
- ☐ History of kidney stones
- ☐ Frequent urination
- ☐ Burning during urination

Page 13 questions (yes/no compulsory)
Do you suffer from any disease of the blood or immune system including anaemia (lack of iron in the body), recurrent infections, HIV/AIDS, leukaemia (cancer of blood cells), or are you using any immunosuppressive medication (inhibit or prevent activity of immune system)?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Please tick the appropriate condition/s that you suffer/ed from
You may tick more than one box if needed

- ☐ Past history of anaemia (lack of iron in the body)
- ☐ Past history of cancer of the blood cells (leukaemia)
- ☐ Past history of cancer of the lymphatic system (lymphoma)
- ☐ Past history of blood disorders
- ☐ History of HIV/AIDS
- ☐ History of a supressed immune system

Page 14 questions (yes/no compulsory)
Do you suffer from any growths or cancer including a past history of cancer?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Please tick the appropriate condition/s that you suffer/ed from
You may tick more than one box if needed

- ☐ Past history of cancer

☐ Current undiagnosed growth

Page 15 questions (yes/no compulsory)
Do you suffer from any allergies including a past history of allergies to medication, plant material or animal material?

○ Yes

○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Please tick the appropriate condition/s that you suffer/ed from
You may tick more than one box if needed

☐ Past history of allergies to medication

☐ Past history of allergies to plant material

☐ Past history of allergies to animal material

☐ History of any other allergies

Have you ever needed to use adrenalin to control your allergic symptom or have you been advised to carry an adrenalin pen (Epipen®)

○ Yes

○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Please tick the appropriate box
You may tick more than one box if needed

☐ I used adrenalin to control allergic symptoms

☐ I have been advised to carry an adrenalin pen (Epipen ®)

Page 16 questions (yes/no compulsory)
At the moment, do you use any prescribed medication on a daily, weekly or monthly basis to treat chronic (long-term) medical conditions or injuries?

○ Yes

○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
Pease tick the type of medication/s that you are taking from the list below:

You may tick more than one box if needed. If your medication type is not on the list please enter it in the free text box that is below the list.

☐ Cholesterol lowering medication

- [ ] Blood pressure lowering medication
- [ ] Medication to control heart rhythm
- [ ] Medication to treat heart failure
  Medication to prevent blood clots (blood thinners)
- [ ] Other medication to treat heart disease
- [ ] Medication (tablets) to treat type 2 diabetes
- [ ] Insulin for diabetes
- [ ] Medication to treat anxiety
- [ ] Anti-depressant medication
  Medication to improve concentration
  Medication to stop smoking
- [ ] Anti-asthma medication
  Medication to treat long standing joint problems (rheumatoid arthritis)
  Medication to treat thyroid disease
  Hormone therapy i.e. oestrogen, progesterone, oral contraception
  Medication to control long standing inflammation i.e. cortisone, immune suppressants
  Medication to control gastrointestinal related problems i.e. spastic colon, reflux, Chrohns disease, Ulcerative Colitis
  Herbal medication to treat joint or muscle ailments
- [ ] Other medication (please list in box below)

Page 17 questions (yes/no compulsory)

Have you ever in your cycling career used medicines to treat injuries in the week before or during a race – including anti-inflammatory drugs, cortisone (pills, or injection), or pain killers?

- ○ Yes
- ○ No

If no response, go to next page
If yes response, then drop down the following boxes on same page (compulsory to select at least one)

Which of the following medicines have you used in the past to treat an injury in the week just BEFORE a race?

- [ ] Paracetamol (e.g. Panado, Tylenol)
- [ ] Non-steroidal anti-inflammatories (e.g. Voltaren, Cataflam)
- [ ] Cortisone (pills)
- [ ] Cortisone injection
- [ ] Codeine

- [ ] Anti-inflammatory gels/creams/patches
- [ ] Any other pain killers
  Herbal medication

Which of the following medicines have you used in the past to treat an injury DURING a race?

- [ ] Paracetamol (e.g. Panado, Tylenol)
- [ ] Non-steroidal anti-inflammatories (e.g. Voltaren, Cataflam)
- [ ] Cortisone (pills)
- [ ] Cortisone injection
- [ ] Codeine
- [ ] Anti-inflammatory gels/creams/patches
- [ ] Any other pain killers

Page 18a and b questions (yes/no compulsory)
If no, proceed to Page 19
If yes, proceed to 18b
Do you or did you suffer from any symptoms of a CHRONIC (no accident) cycling injury (muscles, tendons, bones, ligaments or joints) IN YOUR CYCLING CAREER?

(NB: Only if an injury is/was severe enough to interfere with cycling, or require treatment e.g. use medication, or require you to seek medical advice from a health professional)

- ○ Yes
- ○ No

Injury 1

Page 18b questions (yes/no compulsory)
Do you or did you suffer from any symptoms of a CHRONIC cycling injury (muscles, tendons, bones, ligaments or joints) IN THE PAST 12 MONTHS OR CURRENTLY?

(NB: Only if an injury is/was severe enough to interfere with cycling, or require treatment e.g. use medication, or require you to seek medical advice from a health professional)

- ○ Yes
- ○ No

If no response to 18b, go to next page
If yes response to 18b, then drop down the following box on same page (compulsory to select at least one)

Pease tick if past or current:

- Past
- Current

How long ago did you first become aware of the CHRONIC injury? (months)

_____ months

Please indicate which side of your body is injured (if applicable)

- Right
- Left
- Both

Please indicate which anatomical area is/was injured (single select)

- Head
- Neck
- Face
- Front chest
- Back chest
- Shoulder
- Upper arm
- Elbow
- Forearm
- Wrist
- Finger
- Lower back
- Hip
- Groin
- Hip muscle (including gluteus / buttock muscles)
- Hamstring muscle
- Quadriceps muscle
- Calf muscle
- Knee
- Shin / Lower leg
- Achilles
- Ankle
- Foot
- Other, please specify

Please indicate the type of structure that was injured (single select)

- [ ] Muscle (e.g. strain)
- [ ] Ligament (e.g. sprain)
- [ ] Tendon
- [ ] Joint (e.g. arthritis)
- [ ] Nerve (e.g. numbness during or after cycling)
- [ ] Bone (e.g. bruise or stress fracture)
- [ ] Other, please specify

Please indicate if your injury was any of the following more common cycling injuries (single select)

- [ ] Knee - Patellofemoral pain / anterior knee pain
- [ ] Knee - Iliotibial band (ITB)
- [ ] Neck pain
- [ ] Lower back pain
- [ ] Groin / genital numbness
- [ ] Saddle sores
- [ ] Hip joint pain
- [ ] Hip muscle injury (including gluteus / buttock muscles)
- [ ] Hamstring injury
- [ ] Quadriceps muscle injury
- [ ] Achilles tendon injury
- [ ] Calf muscle injury
- [ ] Foot or heel pain
- [ ] Shoulder pain
- [ ] Elbow pain
- [ ] Wrist pain
- [ ] Numbness in the hand / fingers
- [ ] Other, please specify

Please indicate the severity of the injury

- ○ I only experience symptoms after exercise
- ○ I experience symptoms during exercise, but it does not interfere with exercise
- ○ I experience symptoms during exercise that may interfere with my training/ competition

- ○ I am so painful that I may not be able to train or compete

Please indicate how your injury was treated to date (you can tick more than one)?

- ☐ Rest
- ☐ Tablets
- ☐ Stretches
- ☐ Cortisone injection
- ☐ Physiotherapy
- ☐ Other injection
- ☐ Surgery
- ☐ Bicycle set-up
- ☐ Strengthening exercises
- ☐ Equipment change (cycling pants)
- ☐ Equipment change (cycling gloves)
- ☐ Equipment change (cycling shoes)
- ☐ Other, please specify

Would you like to list another important CHRONIC cycling injury?

- ○ Yes
- ○ No

If no response, go to next page 19
If yes response, then drop down the following box on same page (compulsory to select at least one)
(At this point, there is an option to complete details for more than one injury using the same data capture procedure for the first injury)

Page 19a questions (yes/no compulsory)
Do you or did you suffer from any symptoms of a ACUTE ACCIDENTAL cycling injury (muscles, tendons, bones, ligaments or joints) IN THE PAST 12 MONTHS OR CURRENTLY?

(NB: Only if an injury is/was severe enough to interfere with cycling, or require treatment e.g. use medication, or require you to seek medical advice from a health professional)

- ○ Yes
- ○ No

If no response to 19a, go to next page 20
If yes response to 19a, then drop down the following box on same page (compulsory to select at least one)

Pease tick if past or current:

- Past acute injury (accident)
- Current acute injury (accident)

How long ago did your ACUTE ACCIDENTAL injury occur? (weeks)

_____ weeks

Please indicate which side of your body is injured (if applicable)

- Right
- Left
- Both

Please indicate which MAIN anatomical area is/was injured in the accident (single select)

- Head
- Neck
- Face
- Front chest
- Back chest
  Front abdomen
  Flank -back
- Shoulder
- Upper arm
- Elbow
- Forearm
- Wrist and hand
- Finger
- Lower back
- Hip
- Groin
- Hip muscle (including gluteus / buttock muscles)
- Hamstring muscle
- Quadriceps muscle
- Calf muscle
- Knee
- Shin / Lower leg
- Achilles
- Ankle

- [ ] Foot
- [ ] Other, please specify

Please indicate the type of injury occurred in the MAIN anatomical area that was affected (single select)

- [ ] Muscle strain
- [ ] Muscle rupture
- [ ] Tendon rupture
- [ ] Ligament sprain
- [ ] Ligament rupture
- [ ] Joint cartilage tear / injury
- [ ] Joint dislocation
- [ ] Significant skin injury (laceration or graze)
- [ ] Nerve (e.g. numbness or loss of muscle power)
- [ ] Bone (fracture)
- [ ] Bone (bruise)
- [ ] Head injury (fracture)
- [ ] Head injury (concussion)
  Internal organ injury i.e. lung, spleen , liver, heart, intestines, kidney ,bladder
- [ ] Other, please specify

Please indicate the severity of the ACUTE injury by indicating how many days were you not able to cycle following the injury

- ○ 1-7 days
- ○ 7-14 days
- ○ 14-28 days
- ○ > 28 days

Please indicate how your ACUTE injury was treated to date (you can tick more than one)?

- [ ] Rest
- [ ] Tablets
- [ ] Injections
- [ ] Physiotherapy
- [ ] Rehabilitation
- [ ] Surgery

☐ Other, please specify

Would you like to list another important ACUTE ACCIDENTAL cycling injury?

○ Yes

○ No

If no response, go to next page 20
If yes response, then drop down the following box on same page (compulsory to select at least one)
(At this point, there is an option to complete details for more than one ACUTE injury using the same data capture procedure for the first injury)

Page 20 questions (yes/no compulsory) (Can this question only come up after certain questions – listed in email)
Have you consulted with a medical doctor in the last 12 months to obtain medical clearance that you can safely participate in endurance cycling?

○ Yes

○ No

If no response, go to next page
If yes response, then drop down the following box on same page (compulsory to select at least one)
If yes, please indicate which of the following procedure formed part of the medical assessment for clearance to participate in endurance cycling? (you may tick more than one box if needed)

☐ Your doctor spoke to you only

☐ Your doctor spoke to you and examined you physically

☐ You performed an exercise test but no ECG (electrical leads attached to your chest to measure the hearts response to exercise)

☐ You performed an exercise test with an ECG (electrical leads attached to your chest to measure the hearts response to exercise)

☐ You had an echocardiogram (a sonar of the heart to examine the structure of the heart)

☐ You had blood tests for cholesterol

☐ You had other blood tests

☐ You had other tests (please specify)

After seeing your medical practitioner please indicate which of the following applied?

○ My doctor did not give clearance for me to cycle

○ My doctor did give clearance for me to cycle but with some restrictions and guidelines on safe participation

○ My doctor did give clearance to cycle with no restrictions

Page 21 questions (yes/no compulsory)

Consent for medical information to be used for research purposes

You do also have the opportunity to volunteer that the information on these medical questionnaires can be used for ongoing medical and scientific research to improve race safety and medical care.

The Institute for Sport, Exercise Medicine and Lifestyle Research of the University of Pretoria, in collaboration with the race organizers and the medical team conducts on-going research to improve race safety (protecting the health of the athlete and reducing injury risk). Your participation in this research effort is to improve safety and is entirely voluntary. Please read through the Participant information and then you will be given the opportunity to consent that your information in the medical questionnaires can be included in research studies, and that you can be contacted about participating in other components of the research project that relate to muscle cramps and injuries.

Participant information of the research studies:

The main aim of these studies is to determine if there are any factors that can be identified before the race that will predict whether an athlete is likely to develop a medical problem (including cramps and injuries) during or after the race. The details of the studies are as follows:

- At the race entry and registration, a web-based (or a paper-based) questionnaire detailing personal particulars and medical information, will be completed as part of the race entry and race registration requirements.
- The completion of a questionnaire is not associated with any risk. Questionnaire and other clinical data (paper and electronic) will be kept confidential, will be kept secure, and will not be made available to any party other than the medical and research team without the consent of the individual participant. ☐☐
- You may be contacted before or after the race (by telephone or email), for further information, advice and participation in further research related to injuries or a medical condition (such as cramps) that you developed before, during or after the race. ☐☐
- Volunteering to make medical information available for on-going research has no direct benefit to an individual athlete. However, the long term anticipated benefits of this research are to identify factors that may predispose an increased risk of medical consequences and injury in endurance athletes. This information will eventually assist athletes in decreasing their risk of medical complications and injuries during racing and training.

Consent to participate in the research study

- I understand that I am free to volunteer to participate in the study on pre-race predictors (including medical history, medication use, and injuries) of medical complications that may occur in cyclists before, during and immediately after the race ☐☐
- I understand that my participation in this research project may have no direct benefits to me during the race. However, I understand that my participation in the research project will advance the medical and scientific knowledge related to endurance sports. Therefore, information gathered through my participation in this project could advance the future medical care, training advice and performance of endurance athletes. ☐☐
- I have read the participant information and am satisfied that the procedures and concepts have been explained to me in full. ☐☐
- I agree that all the questionnaire information, my performance during the race, together with all the other data collected from the various components of this study may be used to answer scientific questions about the medical conditions, injuries, physiological responses and measures of performance associated with the preparation, participation in and completion of a race. ☐☐
- I have been informed that the individual data derived from my participation will remain confidential
- I understand that the data obtained from this study may be used for the research components of higher degrees at the University of Pretoria.
- I understand that the Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria has approved the protocol for this research study (REC number 431-2015).
- I understand that each of the medical practitioners involved in the research study on athletes will have up to date professional medical insurance.
- I understand that I can contact members of the research team should I have any questions related to the study. Contact details of the research team are as follows: +27 12 420 3005
- I hereby consent to participate in this study, and that I can be contacted in future for information about research studies on injuries and medical conditions.
- I understand that I may withdraw from this study at any time without further question.

Consent to allow medical information in this questionnaire to be used in ongoing research

☐ Yes, I give consent that the information from the medical questionnaires can be used in ongoing research

☐ No, I do not give consent that the information form the medical questionnaires can be used in ongoing research

Medical questionnaire at the time of registration

Exercise and symptoms of an acute infection

Symptoms of acute illness and infections such as flu, gastro-enteritis (upset stomach) and other infections (e.g. bladder) are more common in athletes just before a race (after periods of peak training). Exercising with symptoms of an infection can increase the risk of medical complications during the race.

The symptoms of infections vary but include the following: generally not feeling well, fever, general muscle pain, general joint pain, general tiredness, headache, sore throat, blocked or runny nose, sore ears, cough, wheeze, diarrhoea, nausea, vomiting, or abdominal cramps/pain.

Please answer the following question so that we can give you advice:

Question 1:

Do you have any of these symptoms of acute illness (today or in the last 7 days)?

No ☐

Yes ☐

Question 2: Symptoms of an acute infection or illness (if yes to question 1)

Symptoms of an acute infection or illness You indicated that you have symptoms of an acute illness **(today or in the last 7 days)** **Please indicate which symptoms do you have?** (Please tick on all the symptoms you have i.e. you may chose more than one) (Based on your responses, you will be sent some information to assist you)	☐ Fever ☐ Sore throat ☐ Runny nose ☐ Blocked nose ☐ Sore ears ☐ Wheezing ☐ Cough ☐ General muscle pains ☐ General joint pains ☐ Headache ☐ General tiredness ☐ Nausea ☐ Vomiting ☐ Diarrhoea ☐ Abdominal pain or cramps ☐ Skin rash / infection ☐ Symptoms of a bladder infection ☐ Any other symptoms (Please specify:)_____

APPENDIX C: INFORMED CONSENT LETTER

MEDICAL CONSEQUENCES IN ENDURANCE SPORTS

CAPE TOWN CYCLE TOUR LONGITUDINAL STUDY: 2016-2018

PARTICIPANT INFORMATION AND INFORMED CONSENT

(COMPONENT 1)

PRE-RACE MEDICAL QUESTIONNAIRES

Dear Cyclist,

Medical questionnaire information for safety on race day

As part on ongoing commitment to making your race experience as safe as possible, and to provide the best medical care we can on race day, the organizers and the medical team are including online medical questionnaires as part of the registration and entry to the race. There are two parts in this process:

a. The completion of an online medical questionnaire (part 1) when you enter for the race
b. The completion of a short medical questionnaire (part 2) in the few days before race registration

The main purpose for this is that the information will allow the medical team to plan medical care for the event and to address important medical consequences and injuries associated with participation in the event. In the interests of your health and safety, the medical team may contact you before or after the event for further information about any medical conditions or injuries you may report in these questionnaires. This information will be of an informative nature to improve race safety.

Medical and scientific research

You do also have the opportunity to volunteer that the information on these medical questionnaires can be used for ongoing medical and scientific research to improve race safety and medical care.

The Institute for Sport, Exercise Medicine and Lifestyle Research the University of Pretoria, in collaboration with the race organizers and the medical team conducts ongoing research to improve race safety (protecting the health of the athlete and reducing injury risk). Your participation in this research effort is to improve safety and is entirely voluntary. Please read through the Participant information and then you will be given the opportunity to consent that your information in the medical questionnaires can be included in research

studies, and that you can be contacted about participating in other components of the research project that relate to muscle cramps and injuries.

Participant information of the research studies:

The main aim of these studies is to determine if there are any factors that can be identified before the race that will predict whether an athlete is likely to develop a medical problem (including cramps and injuries) during or after the race. The details of the studies are as follows:

- At the race entry and registration, a web-based (or a paper-based) questionnaire detailing personal particulars and medical information, will be completed as part of the race entry and race registration requirements.
- The completion of a questionnaire is not associated with any risk. Questionnaire and other clinical data (paper and electronic) will be kept confidential, will be kept secure, and will not be made available to any party other than the medical and research team without the consent of the individual participant. ☐☐
- You may be contacted before or after the race (by telephone or email), for further information, advice and participation in research related to injuries or a medical condition (such as cramps) that you developed before, during or after the race. ☐☐
- Volunteering to make medical information available for ongoing research has no direct benefit to an individual athlete. However, the long term anticipated benefits of this research are to identify factors that may predispose an increased risk of medical consequences and injury in endurance athletes. This information will eventually assist athletes in decreasing their risk of medical complications and injuries during racing and training.

Consent to participate in the research study

- I understand that I am free to volunteer to participate in the study on pre-race predictors (including medical history, medication use, and injuries) of medical complications that may occur in athletes before, during and immediately after the race ☐☐
- I understand that my participation in this research project may have no direct benefits to me during the race. However, I understand that my participation in the research project will advance the medical and scientific knowledge related to endurance sports. Therefore, information gathered through my participation in this project could advance the future medical care, training advice and performance of endurance athletes. ☐☐
- I have read the participant information and am satisfied that the procedures and concepts have been explained to me in full. ☐☐
- I agree that all the questionnaire information, my performance during the race, together with all the other data collected from the various components of this study may be used to answer scientific questions about the medical conditions, injuries, physiological responses and measures of performance associated with the preparation, participation in and completion of a race. ☐☐
- I have been informed that the individual data derived from my participation will remain confidential
- I understand that the data obtained from this study may be used for the research components of higher degrees at the University of Pretoria
- I understand that the Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria has approved the protocol for this research study (REC number (431/2015).
- I understand that each of the medical practitioners involved in the research study on athletes will have up to date professional medical insurance.
- I understand that I can contact members of the research team should I have any questions related to the study. Contact details of the research team are as follows: +27 12 420 3005

- I hereby consent to participate in this study, and that I can be contacted for information about research studies on injuries and medical complications.
- I understand that I may withdraw from this study at any time without further question.

Consent to allow medical information in this questionnaire to be used in ongoing research

Yes, I give consent that the information from the medical questionnaire can be used in ongoing research

No, I do not give consent that the information form the medical questionnaire can be used in ongoing research