Exercise-associated muscle cramping (EAMC) in Ironman triathletes

A dissertation prepared by Nichola Drew (DRWNIC002) in partial fulfilment of the requirements for the Master of Philosophy degree in Sports Medicine (MPhil Sports Medicine) from the University of Cape Town

November 2006

Declaration

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

(Signature)

22/11/2006
(Date)

Acknowledgements

- Heart felt thanks to my two supervisors, Professor Martin Schwellnus and Dr Malcolm Collins, who were so patient, encouraging and knowledgeable! I feel blessed to have worked with such intelligent and warm people.

- Thank you to my 2-year-old son, Tom, for watching "Peter Pan" yet again while Mommy was too busy to give you attention.

- Mom, Dad, Dave and all my family and friends who supported me.

- All the wonderful staff of the UCT/MRC Research Unit for Exercise Science and Sports Medicine, especially Yvonne Blomkamp.

- All those who helped us collect data at the Ironman. It was hard work and fun.

- Lastly and most importantly, the courageous triathletes who inspire us all.

Table of Contents

List of Tables

List of Figures

List of abbreviations

BMI	Body mass index
Cl	Chloride
CR	Cramping group
EAMC	Exercise-associated muscle cramping
GTO	Golgi tendon organ
NC	Non-cramping group
PB	Personal best
K	Potassium
Na	Sodium

Abstract

Exercise-associated muscle cramping (EAMC) is a common condition of spontaneous, painful skeletal muscle spasms that occur in exercising muscles during exercise or in the immediate post-exercise period. There is a high prevalence in endurance athletes, including ultradistance triathletes.

The exact cause for this condition has not been defined but various hypotheses have been proposed. Over the last decade the "fatigue hypothesis" has received most of the support in the scientific literature. Evidence from animal experiments, clinical studies on endurance athletes and situational information, suggest that neuromuscular fatigue may precede the increased neuromuscular excitability leading to EAMC.

The objective of this research study was to identify factors associated with EAMC in endurance triathletes in an attempt to further elucidate the aetiology.

Triathletes competing in the 2006 South African Ironman triathlon were recruited as subjects in a prospective cohort study. A total of 44 triathletes made up the cramping group and 166 the non-cramping group. A detailed questionnaire, including information on training, personal best performances and a cramping history was completed by both groups of triathletes. Full clinical data was also collected from both groups. This included pre-and post race body weights, and pre- and post-race serum electrolyte concentrations.

The main findings of the study were that the two independent risk factors for EAMC in these triathletes were a faster overall race time (and cycling time), and a past history of cramping (in the last 10 races).

Results showed that EAMC was correlated with faster overall and cycle section times. The athletes who had experienced cramps in this event not only achieved faster race times but also predicted faster times, despite similarly matched preparation and performance histories as those who did not cramp. A higher intensity of racing would thus be required by these athletes, predisposing them to premature fatigue. The results thus agree with the "fatigue hypothesis" as an aetiological mechanism for EAMC.

This study also showed no correlation between EAMC and changes in hydration status or changes in serum electrolyte concentration.

This study thus adds to the evidence against disturbances in hydration and electrolyte balance as causes for cramping in exercise and further focuses attention on neuromuscular fatigue as a possible primary factor.

Keywords: exercise-associated muscle cramping (EAMC), neuromuscular fatigue, Ironman triathlon, serum electrolyte concentration, hydration status

Chapter 1

Introduction and scope of the thesis

Exercise-associated muscle cramping (EAMC) is a common and troublesome medical problem in athletes, particularly in endurance athletes [1-5]. This condition has been defined as spontaneous, involuntary spasms that occur in exercising muscles or immediately after cessation of exercise [6]. They are painful and often debilitating contractions [7]. The exact cause of EAMC is, however, still under investigation.

In recent years, researchers at the University of Cape Town's Research Unit for Exercise Science and Sports Medicine have had their attention focussed on determining the aetiology of EAMC [3;6-11]. Following a comprehensive assessment of the available literature in the mid-1990's, a novel hypothesis for the development of EAMC was proposed in by Schwellnus et al [6]. This novel hypothesis challenged the more traditional hypotheses of dehydration, electrolyte disturbances and metabolic abnormalities as causes of EAMC. The basis for the traditional hypotheses is that disturbances in electrolyte and fluid balance (dehydration) precipitate cramping in endurance athletes. This has led to the common belief that correct replacement of water and electrolytes, particularly sodium, will prevent EAMC [12-15].

However, Schwellnus et al. did not find any evidence at that time to support these traditional hypotheses. In their analysis of the literature at that time, they did find evidence to suggest that perhaps the primary factor underlying EAMC is the development of neuromuscular fatigue which, during intense, prolonged exercise leads to progressive increased neuromuscular excitability. In recent years, this group

and others, have shown in a number of studies that the dehydration and serum electrolyte changes are not associated with EAMC in endurance athletes [8;9;16], but that there is some evidence of increased neuromuscular excitability in cramping muscles [9;17].

Determining the exact aetiology and any specific factors associated with EAMC is an ongoing focus of the researchers at this Institute, and this thesis represents ongoing work in this area.

Triathletes, who competed in the 2006 Spec-savers Ironman Triathlon in Port Elizabeth, South Africa, were the focus of the research study presented in this thesis. Triathlon was chosen, because EAMC is still a common and debilitating medical problem in these athletes [1;18]. The specific focus of this research study was to determine factors associated with EAMC in Ironman triathletes, so that triathletes can be given sound clinical advice on measures to prevent and treat EAMC. A prospective cohort study design was chosen so that regression models could be employed to determine independent risk factors for EAMC.

In Chapter 2, the traditional and more recently proposed hypotheses fro the development of EAMC will be reviewed. More specifically, factors that may be associated with the development of EAMC in endurance athletes in general, and triathletes specifically will be reviewed. In Chapter 3, the detailed methodology, results and discussion of the main research study will be presented. Chapter 4 will focus on overall conclusions, practical recommendations and directions for future studies.

Chapter 2

Exercise-associated muscle cramping (EAMC) in triathletes: A review

2.1. Introduction

Exercise-associated muscle cramps (EAMC) is one of the most common conditions that require medical attention during or immediately after ultra-endurance sports events. EAMC is particularly common in ultra-marathon running and triathlon events [19-22]. Despite the high prevalence of this condition reported amongst endurance athletes, the factors associated with the development of EAMC in endurance athletes, and specifically triathletes, are still not well understood.

It is important to point out that muscle cramping in athletes may also occur as a result of many underlying medical conditions [23]. In a recently published review article cramps in athletes has been classified under "Paraphysiological cramps" as "Cramps during sporting activity" [23]. However, in the Sports Medicine literature, cramping during or immediately after exercise is more commonly referred to as Exercise-associated muscle cramping (EAMC) [8;9;24]. In accordance with the common use of the term EAMC in the Sports Medicine literature, this term will be used in this thesis, rather than the term "Cramps during sporting activity" [23].

Because it is important to differentiate EAMC from other causes of skeletal muscle cramping, the classification and terminology related to EAMC will first be reviewed in this Chapter. Secondly, the epidemiology of EAMC amongst athletes from various sports, but particularly in triathletes, will be briefly reviewed. Thirdly, the "traditional"

hypotheses for the aetiology of EAMC, including the role of serum electrolyte abnormalities, hydration status, metabolic abnormalities and environmental factors in muscle cramping will de discussed. A novel hypothesis for the aetiology of EAMC had been proposed about 10 years ago [6]. This hypothesis suggested that muscle fatigue may be the primary factor that is associated with the development of EAMC. The muscle fatigue hypothesis has only recently gained some acceptance, and the evidence in support of this hypothesis will also be discussed in this review chapter. Finally, factors that are associated with the development of EAMC in triathletes, which is the specific focus of this thesis, will be reviewed.

2.2. Definition and classification of EAMC

Muscle cramping can occur as part of the general symptom complex of a variety of medical conditions. Medical conditions and abnormalities where muscle cramping can occur have recently been reviewed (Table 2.1) [23]. It is not within the scope of this thesis to discuss all these medical conditions. This review will therefore focus solely on exercise-associated muscle cramping (EAMC).

It is important to point out that EAMC excludes 1) cramps that occur in smooth muscle, 2) cramping that occurs in skeletal muscle at rest and 3) muscle cramping that is associated with any underlying disease or use of drugs [6]. For the purpose of this thesis and in this review, EAMC will therefore refer only to cramping during exercise and will be defined as a "painful, spasmodic and involuntary contraction of skeletal muscle that occurs during or immediately after exercise" [6].

Table 2.1.: Classification of muscle cramps

(Adapted from: L Parisi, et al. Muscular cramps: Proposals for a new classification. *Acta Neurol Scand* 2003; 107: 179 [23])

Paraphysiological	Occasional cramps	
	Exercise Associated Muscle Cramps (EAMC)	
	Pregnancy	
Idiopathic	Familial	• Autosomal dominant cramping disease • Nocturnal cramps Continuous muscle fibre activity syndrome
	Sporadic	• Continuous muscle fibre activity syndrome (Isaac's syndrome, Stiff-man syndrome, cramp-fasciculation syndrome, myokymia-cramp syndrome) • Syndrome of progressive muscle spasm, alopecia, and diarrhea (Sathoyoshi's syndrome) • Idiopathic nocturnal cramps • Idiopathic generalised myokymia • Myokymia-hyperhidrosis syndrome
	Others	• Familial insulin resistance with acanthocythosis and acral hypertrophy • Muscle cramps in cancer
Symptomatic	Central and peripheral nervous system diseases	• Motorneuron disease • Occupational dystonias • Parkinson's disease • Tetanus • Multiple sclerosis • Radiculopathies • Plexopathies • Peripheral neuropathies (inherited, endocrin-metabolic, infectious, toxic inflammatory demielinizing) • Others (rare) (neurolathyrism, familial paroxysmal dystonic choreoathetosis)
	Muscular diseases	• Metabolic myopathy (deficiency of myophosphorilase, phosfophruttokinase, phosfogliceromutase, phosfoglicerokinase, lactate dehydrogenase (LDH), adenylate deaminase, G6PDH, phosforylase b-kinase) • Mitochondrial myopathy (Carnitine deficiency, CPT1 e 2 deficiency) • Endocrine myopathy (Hoffman's syndrome, etc) • Dystrophinopathies (Duchenne, Becker, and others) • Myotonia (homsen, Becker, rippling syndrome) • Inflammatory myopathies (Myositis, myopathy with tubular aggregates, rheumathic polymyagia) • Others (rare) (Lambert-Brody's diseases, Swartz-Jampel syndrome, eosinophilia-myalgia syndrome type 2 muscle fibre myopathy)
	Cardiovascular diseases	• Venous diseases • Arterial diseases • Heart diseases • Hypertension
	Endocrine-metabolic disease	• Hypo-hyperthyroidism • Hypo- hyperparathyroidism • Isolated deficiency of ACTH accompanied by generalised painful muscle cramp • Cirrhosis • Bartter's syndrome • Gitelman's syndrome • Conn's disease • Addison's disease • Uremia and dialysis
	Hydro-electrolyte disorders	• Dehydration with or without electrolytes imbalance (diarrhoea and vomiting, etc) • Hypo-hypernatremia • Hypo-hypercalcemia • Hypo-hyperkalemia • Hypomagnesemia • Heat cramps
	Toxic and pharmacological causes	• Drugs • Pesticides • Black widow spider bite • Toxic oil syndrome Malignant hyperthermia
	Psychiatric disorders	

2.3. Epidemiology of EAMC

Prevalence can be defined as the "overall proportion of a population who suffer from a disease" [25]. The lifetime prevalence of EAMC can thus be defined as the number of athletes who have ever experienced EAMC at some time in their athletic career. The lifetime prevalence of EAMC in different sports has not been well documented. However, the lifetime prevalence of EAMC in sports, where this has been reported, presented in Table 2.2. These data show that EAMC is common in sport, and it appears that the prevalence of EAMC increases as a function of the intensity and duration of the activity, with the highest lifetime prevalence of EAMC being reported in triathletes.

Table 2.2.: Lifetime prevalence of EAMC (%) for various sports

Activity	Lifetime prevalence (%)	Reference
Rugby	52%	[11]
Cycling	60%	[3]
Marathon (42.2km)	39%	[5]
Triathlon	67-68%	[1;18]

Despite the high reported prevalence of EAMC amongst triathletes, there have only been a few studies reporting on the lifetime prevalence of EAMC in triathletes. In one study, the nature and prevalence of muscle cramping in United States Triathlon Series participants was reported [1]. In this study, 2600 athletes who had participated in a series of triathlons in the United States of America were surveyed, and cramping episodes were reported in 67% of the respondents. In this survey, running was the

activity that most often precipitated cramps, but only 4% of triathletes suffered from severe cramps. The cycle leg and swim leg of the triathlon only accounted for 15% and 14% of cramps, respectively in this study [1].

In another cross-sectional descriptive study of the Ironman triathletes who participated in the 2001 South African Ironman Triathlon, 68.5% of triathletes reported a past history of EAMC [18]. This study confirmed the result of the previous survey that there is a high lifetime prevalence of EAMC in Ironman triathletes. Furthermore, in this study, EAMC in triathletes was associated with running, racing and the development of muscle fatigue. EAMC in triathletes occurred mostly in the last quarter of a race.

It is clear that EAMC has not been thoroughly researched in either triathletes or Ironman triathletes and not much is known about the factors associated with the development of EAMC in triathletes. Therefore this thesis will focus on identifying factors associated with the development of EAMC in Ironman triathletes.

2.4. Aetiology of EAMC

2.4.1. Historical background

The first reports of muscle cramping related to physical activity were from labourers working on steamships and in mines in hot, humid conditions at the turn of the 20th century [26;26;27]. In these early reports it was noted that cramping not only occurred in the heat but that cramps were also accompanied by profuse sweating [26]. These anecdotal observations led to the still commonly accepted "serum electrolyte" and

"dehydration" hypotheses for the aetiology of EAMC. In the early 1950's a patient suffering from exertional muscle cramps was found to have a deficiency of myophosphorylase [28]. Several other metabolic abnormalities associated with cramping were subsequently reported, which resulted in the development of the "metabolic abnormality" hypothesis for the aetiology of muscle cramping [29;30]. Case reports of cramping in extremely hot conditions have given rise to the "environmental" hypothesis for the aetiology of EAMC [26], and to date, "heat cramps" are still included in recently published classification on the causes of cramps [23]. These "traditional hypotheses" for the aetiology of EAMC will now be discussed in detail.

2.4.2 Serum electrolyte hypothesis

At the turn of the 20th century it was noted that patients exposed to physical exercise in hot and humid environments developed muscle cramps and that this was reportedly associated with hyponatraemia and hypochloraemia [27;31]. Other serum electrolyte abnormalities, including hyperkaleamia, hypomagnesaemia and hypocalcaemia, have also been associated with EAMC [26;32;33;34]. The majority of these reports were based solely on anecdotal observations, however, with no proposed mechanism to explain how such imbalances in serum electrolytes could result in localized muscle cramping. Despite this, many published texts [35-37], including more recent ones [15;38] still support the role of altered serum electrolyte concentrations in the development of EAMC.[15;35;36;38]

Experimentally induced hyponatraemia, if accompanied by sodium loss, has been associated with generalized skeletal muscle cramping at rest [39;40]. Altered serum

electrolyte concentrations caused by systemic abnormalities can result in generalized skeletal muscle cramping [7]. However, it is important to note that in the majority of athletes with EAMC, cramping only occurs in the localized muscle groups involved in the repetitive contractions associated with exercise [41]. Thus results from studies which have examined the relationship between serum electrolyte abnormalities in systemic diseases and in skeletal muscle at rest may not be applicable to EAMC [6].

However, there are now three prospective cohort studies that have examined the relationship between serum electrolyte abnormalities and EAMC in marathon runners [8;9;42], one of which was conducted studying a cohort of Ironman triathletes [9;17]. In the first study serum electrolyte concentrations (sodium, potassium, calcium, phosphate) were documented in marathon runners with acute EAMC (n=15) and control runners (n=67) before and immediately after the race [42]. In this study there were no significant differences in serum electrolyte concentrations between the two groups and it was concluded that the results "failed to produce any support for the suggestion that muscle cramp is the result of gross disturbances of electrolyte balance".

In a more recent study in ultra-marathon runners no significant differences in serum electrolyte concentrations (sodium, potassium, magnesium, calcium) were recorded between runners with acute EAMC (n=21) and control runners (n=22) either before, immediately after the run or after 60 minutes of recovery [8]. In this study it was concluded that there was a complete dissociation between EAMC and changes in serum electrolyte concentrations.

Most recently, the results of a similar study on serum electrolytes in Ironman triathletes participating in the 2000 South African Ironman Triathlon that experienced EAMC and those that did not were reported [9]. In this study, post-race serum sodium, potassium, chloride, magnesium and glucose, as well as hemoglobin concentration and hematocrit were measured in 11 triathletes who suffered EAMC and 9 who did not. Results again showed a statistically significant but not a clinically significant decrease in sodium concentration post-race in those that suffered EAMC. Once again, the results of this study show a dissociation between serum electrolyte concentrations and the development of EAMC.

The findings of these three prospective studies therefore do not support an association between EAMC and abnormalities in serum electrolyte concentrations. Despite this recent evidence, the "serum electrolyte" theory is still widely accepted and remains a contentious issue. Serum electrolyte concentrations of cramping runners have been reported in three studies, but only one study has investigated the serum electrolyte concentrations of cramping Ironman triathletes. Therefore, this thesis will also focus on the serum electrolyte concentrations of cramping and non-cramping (control) Ironman triathletes.

2.4.3 Dehydration hypothesis

Dehydration is often implicated as a cause of EAMC and is cited in textbooks as a cause for muscle cramps in athletes [14;36]. The dehydration hypothesis for the cause of EAMC has its roots in the early part of the twentieth century when case series reports linked cramping in mine workers to excessive sweating and presumed

dehydration [26]. These were once again anecdotal observations and no actual measures of hydration status were reported.

To date, actual evidence that dehydration may be a cause for EAMC comes from three studies where the relationship between hydration status and EAMC has been documented [8;9;17;42]. In these studies body weight changes, calculated blood volume and calculated plasma volume were used as an indication of hydration status. In the first study no significant differences in hydration status between marathon runners with EAMC (n=15) and control marathon runners (n=67) was documented it the authors concluded that EAMC was not associated with changes in fluid balance [42]. These findings were supported by the results of the second study which also found no significant differences in hydration status between ultra-distance runners with EAMC (n=21) and control runners (n=22) [8].

In the only study in Ironman triathletes published to date, changes in body weight over the Ironman event were similar in triathlete experiencing EAMC (n=11) compared with non-cramping control triathletes (n=9) [9].

The findings of all three these studies relating measures of hydration status to EAMC, do not support the hypothesis of a direct relationship between dehydration and muscle cramping in runners. Yet, this too remains a contentious issue. Thus, measures of hydration status as factor associated with EAMC in Ironman triathletes will also be investigated in this thesis.

2.4.4 Metabolic abnormality hypothesis

Various inherited metabolic abnormalities are associated with skeletal muscle cramping during exercise (Table 2.1) [23]. Although cramping is a common symptom between these inherited metabolic abnormalities and EAMC, it is important to note that there are fundamental differences between the clinical features of these inherited metabolic abnormalities and EAMC [6]. In addition, these metabolic abnormalities are rare, while EAMC is very common. Patients suffering from these metabolic abnormalities also have a very low effort tolerance, whereas EAMC is common in elite athletes. There is therefore little support for the hypothesis that the most common form of EAMC is caused by inherited metabolic abnormalities and this hypothesis will not be investigated further in this thesis.

2.4.5. Environmental extremes hypothesis

The term 'heat cramps' was first used to describe cramps associated with physical exercise in hot and humid conditions [26]. Although EAMC is often associated with exercising in the heat, cramping has also been reported in marathon runners in cool weather [4]. It has also been reported that the development of EAMC is not directly related to an increased core temperature [42]. Furthermore, passive heating alone (at rest) does not result in EAMC and cooling does not relieve muscle cramps [6]. Indeed, exposure to extreme cold has also been associated with EAMC in swimmers [21]. It would appear that heat alone is not a direct cause of muscle cramping during exercise. This hypothesis will not be investigated further in this thesis.

In summary, there are many hypotheses for the aetiology of EAMC, and these are based mostly on anecdotal evidence. As discussed, evidence from recent studies does not appear to support these "traditional" hypotheses for the development of EAMC in athletes. As previously mentioned, a novel hypothesis for the development of EMAC was first proposed 10 years ago [6]. The rationale for proposing muscle fatigue as the common aetiological factor in the development of EAMC in athletes, including evidence from recent studies to support this hypothesis, will now be reviewed.

2.4.6. The "muscle fatigue" hypothesis for the aetiology of EAMC

It has been suggested that muscle cramping is primarily an abnormality of skeletal muscle relaxation [43]. Muscle fatigue has been shown to disrupt the functioning of the peripheral receptors that play an important role in skeletal muscle relaxation [44;45]. It has also been observed clinically, that the majority of athletes that develop EAMC report a subjective feeling of muscle fatigue prior to the onset of muscle cramping [3;5;10;11]. It is on the basis of this evidence that the "muscle fatigue" hypothesis for the aetiology of EAMC was first proposed. This hypothesis suggests that EAMC is the result of an abnormality of alpha motor neuron control at the spinal level [6].

Muscle fatigue has been shown to disrupt the functioning of the peripheral muscle receptors by causing an increased firing rate of the muscle spindle's type Ia and II afferents, as well as a decrease in the type Ib afferent activity from the Golgi tendon organ [44;45]. As muscle fatigue develops during prolonged intense exercise, it is therefore possible that a combination of the increased excitatory activity of the

muscle spindle and a reduced inhibitory effect of the Golgi tendon organ with muscle fatigue would result in a sustained alpha motor neuron activity caused by an abnormality of the alpha motor neuron control at the spinal level [6]. Clinically, and when measuring electromyographic activity, this would present as muscle fasciculation and increased EMG activity respectively.

It has also been observed that cramping can be induced when muscles are contracted in a shortened position [46;47]. Contracting a muscle in its shortened position would decrease the tension in the tendons of the muscle during contraction and further decrease the inhibitory afferent activity from the type Ib afferents of the Golgi tendon organ [6]. Furthermore, passive stretching is the most common and effective therapy to relieve acute muscle cramping [46;48-51] Passive stretching increases the tension in a muscle, thereby increasing the Golgi tendon organ's inhibitory activity [45]. The effectiveness of passive stretching in treating EAMC offers further support for the hypothesis that abnormal spinal reflex activity is associated with EAMC [6]. This hypothesis would also explain the increased baseline EMG activity recorded between bouts of cramping in athletes suffering from EAMC after fatiguing exercise [17]. In a recently published study, in Ironman triathletes, baseline surface electromyographic (EMG) activity (between bouts of acute cramping) was significantly higher in the cramping muscle compared with a non-cramping control muscle in the same athlete [9]. This finding indicates that cramping muscles exhibit increased neuromuscular excitability. The authors of this study acknowledge that although these findings have to be interpreted with caution, but the observed heightened neuromuscular excitability could possibly be associated with muscle fatigue [9]. This would require further study.

Unlike the "traditional" hypotheses for the aetiology of EAMC, the "muscle fatigue" hypothesis is based on evidence from epidemiological studies, animal experimental data on spinal reflex activity during fatigue and EMG data recorded during bouts of acute cramping after fatiguing exercise [7]. It is, however, clear that further evidence to support the "muscle fatigue" hypothesis is required. One finding that would support this hypothesis is if athletes that exercise at higher intensity during a training session or a competition are more likely to develop EAMC.

In a recently published study, it has been shown that a laboratory-based exercise protocol, specifically designed to cause premature fatigue of the calf muscles, resulted in a high incidence of muscle cramping during exercise. However, it would be important to confirm this finding during a field study, where athletes exercising at a higher intensity are shown to be at greater risk for the development of EAMC. In Chapter 3 of this thesis, this relationship will be further explored.

2.5. Factors associated with the development of EAMC

Although the exact nature of EAMC is still unclear, anecdotal clinical observations and results from epidemiological studies have identified some factors that may be associated with EAMC. In one epidemiological study of over 1 300 marathon runners, older age, a longer history of running, higher body mass index, shorter daily stretching time and irregular stretching habits were identified as possible risk factors associated with EAMC [10]. An observation from these results is that poor stretching

habits seem to be associated with an increased risk for EAMC. It is well accepted that passive stretching provides relief from muscle cramping [46;48-51]

High-intensity running (racing), subjective muscle fatigue, hill running and poor race performance were also reported to be associated with EAMC in the epidemiological study of marathon runners [10]. It has also been reported that EAMC is more common in less well-trained athletes, which supports the suggestion that subjective muscle fatigue and poor race performance may be associated with EAMC [52]. It is well documented that most cramping episodes occur in the later stages of a race, usually after 30km in a standard marathon and in the late run stage of an Ironman Triathlon, which suggests that a long duration of running may also be associated with EAMC [1;10;42].

In one study, the association between a positive family history of muscle cramping and the development of EAMC in 1 383 marathon runners was reported [10]. In this study, 19% of cramping marathon runners reported a positive family history of cramping compared with 10% of non-cramping runners [10].

It is clear that, apart from one study in marathon runners, factors associated with EAMC in endurance athletes in general, and triathletes specifically are not well documented. This experimental component of this thesis will therefore focus on identifying factors associated with EAMC in Ironman triathletes.

2.6. Summary

In summary, a review of the literature on the epidemiology, aetiology, and risk factors for EAMC in endurance athletes, and specifically in triathletes, reveals the following:

- There is a high lifetime prevalence of EAMC in athletes, specifically in endurance athletes such as triathletes
- Despite this high prevalence, there is little attention given to this common medical problem in the scientific literature
- There are a number of "traditional" hypotheses for the development of EAMC in endurance athletes, including "serum electrolyte disturbances" , "dehydration", "extreme environments" and inherited "metabolic abnormalities"
- A careful analysis of the existing scientific data, including data from recently published prospective studies, do not support the hypotheses that EAMC is caused by serum electrolyte disturbances or dehydration
- Evidence from animal experiments, clinical observations, and EMG studies indicate that the development of premature "muscle fatigue" during exercise is a more plausible hypothesis explaining the development of EAMC
- Factors associated with the development of EAMC have been identified, but only from one study in marathon runners
- There are no data from prospective studies, identifying independent risk factors for EAMC in triathletes

Chapter 3

Factors associated with exercise-associated muscle cramping (EAMC) in Ironman triathletes

3.1. Introduction

The triathlon is a physically demanding event consisting of a swimming, a cycling and a running component. The Ironman triathlon, which consists of a 3.8 km open water swim, a 180 km road cycle and a 42.2 km run, is the most challenging of all the triathlon events. Competitors range from the elite triathlete to the heroic average battler. A number of medical problems are encountered by athletes participating in the Ironman triathlon, and these have recently been reviewed [53]. Of particular interest are consistent reports that skeletal muscle cramping accounts for between 6% to 20% of medical diagnoses in triathletes [19;21]. Skeletal muscle cramping is therefore one of the most common medical problems encountered by the competitors in an Ironman event [1,21].

Exercise-associated muscle cramping (EAMC) can be defined as a syndrome of involuntary painful skeletal muscle spasms, that occur during or immediately after physical exercise [6]. EAMC usually presents as painful localized muscle cramping that occurs spasmodically in different exercising muscle groups - usually the calf, hamstring or quadriceps muscles [7]. EAMC should be distinguished from generalized involuntary muscle contractions in non-exercising muscles which are associated with a number of acute or chronic and congenital or acquired medical conditions [23].

Although EAMC is common in triathletes, the precise risk factors and pathophysiology of the condition is still not well researched, and remains controversial. A number of hypotheses concerning the aetiology of EAMC have, been proposed. The more traditional hypotheses state that heat, dehydration, electrolyte disturbances or metabolic abnormalities are the cause of EAMC [6]. However, recently published research from two studies has shown that there is no relationship between 1) serum electrolyte changes and the development of EAMC [8;9;42], and 2) measures of dehydration and the development of EAMC [8;9]. In one of these studies, Ironman triathletes were studied [9]. Despite these findings, triathletes, coaches and scientists [12-15] still remain to be convinced that dehydration and electrolyte imbalances are not necessarily related to the development of EAMC.

In 1997, a novel "muscle fatigue" hypothesis for the development of EAMC has been introduced [6]. Based on data from clinical observations and animal studies, this hypothesis suggests that the development of "neuromuscular fatigue" leads to abnormally increased neuromuscular excitability. In support of this hypothesis, it has been documented that fatigue increases the muscle spindle afferent activity and decreases the Golgi tendon organ afferent activity [44;45], which may results in increased alpha motor neuron activity. Therefore as progressive muscle fatigue develops, there may be an increased risk of developing EAMC [6]. Recently, it has been shown that there is increased baseline electromyographic (EMG) activity in triathletes suffering from EAMC immediately after the race, when compared with a non-exercising control muscle [9;17].

The Ironman triathlon, where the risk of developing EAMC is high, is therefore an ideal model to study the risk factors and possible aetiological mechanisms for the development of EAMC. In particular, a prospective cohort study design would be suitable as a model for studying risk factors for EAMC in these athletes.

The aim of this study was therefore to determine the risk factors for exercise-associated muscle cramping (EAMC) in a cohort of triathletes participating in an Ironman triathlon.

3.2. Methods

3.2.1. Subjects

All 1136 triathletes (970 male, 85.4% and 166 female, 14.6%) who entered the 2006 "Spec-savers" Port Elizabeth South African Ironman Triathlon (3.8 km swim, 180 km cycle and a 42.2 km run), which was held during March 2006, were considered as potential subjects. In the 2 months prior to the event, information about the study was posted on to the official race website (Appendix 1). This information included details about the study procedures (Appendix 2), informed consent form (Appendix 3) copies of the questionnaires (Appendix 4) to be completed, and a service for triathletes to ask questions about the research by telephone or email. Prior to the study, the protocol was approved by the Faculty of Health Science's Research Ethics Committee of the University of Cape Town (REC ref no 425/2005) (Appendix 5), as well as the general organizing committee and the medical sub-committee of the 2006 "Spec-savers" Port Elizabeth South African Ironman Triathlon.

Recruitment for the study took place at the registration area during the 3 days prior to the event. A research area was established in close proximity to the triathlon registration desk. As triathletes reported at the registration desk, they were informed about the nature of the study, and could then volunteer to take part in the study. Triathletes then reported to the research staff, where further information was given, and any questions were answered. Of the 1136 triathletes who entered the event, 992 (87.3%) started the race and 399 (35.1%) consented to be part of the study.

Once triathletes gave written consent to be part of the study, they continued with completion of a pre-race questionnaire, as well as having a blood sample taken. In addition, triathletes agreed to a) report to a designated pre-race weigh-in area, just before they started the event on race day, b) report to the immediate post-race weigh-in area which was located in the "tunnel" just after the finish line where post-race body weights as well as post-race blood samples were taken and c) complete an abbreviated post-race questionnaire which was sent by email to them in the first 7 days after the race.

3.2.2. Pre-race questionnaire

For the purposes of this study, a previously validated pre-race questionnaire was modified and then used [9;54;55]. The pre-race questionnaire consisted of various sections and included details of each triathlete's personal particulars, family and personal medical history, estimated fluid use, as well as, training and racing history. The information obtained from this questionnaire was used in a number of studies

that were conducted at this event. In this particular study, information from the following sections was used: (1) demographic details (including age, height, weight and gender), (2) previous participation in cycling, running and Ironman events (including personal best times), (3) training details in the last 15 weeks before the event (training distances and hours spent training), (4) frequency of flexibility training and stretching exercises, (5) family history of exercise-associated muscle cramps (EAMC) and nocturnal cramps, (6) anticipated fluid intake during the event (type, amount and frequency), (7) personal general medical history, including previous EAMC and recent flu-like symptoms, and finally, (8) medication and supplement usage.

Triathletes were encouraged to complete the questionnaire whilst remaining in the research area, and the majority completed it in this manner. Alternatively, triathletes took the questionnaire with them and returned it the next day or the morning of the race (< 10% of questionnaires were returned this way). The pre-race questionnaire was completed by 304 (76.2%) of the 399 athletes.

3.2.3. Pre-race blood sample and biochemical analysis

A pre-race blood sample was drawn at registration (1-3 days before the triathlon). A 5 ml venous blood sample was taken from the ante-cubital vein while the subject was seated. A lithium heparin Vacutainer tube was used, and the sample was immediately centrifuged at 3000 × g for 10 minutes at 4°C. The serum was stored at -20°C until analysis was done at a later stage. Serum sodium, potassium and chloride

concentrations were determined in the pre- and post race samples using an EasyLyte PLUS Na/K/Cl analyzer (Medica Corp., Bedford, MA).

3.2.4. Pre-race body weight measurement

Pre-race body weight measurements were taken on the morning of the race, before the start of the swimming leg (not more than 60 min before race start) using calibrated electronic scales (Beurer GmbH & Co., Ulm, Germany). All the scales were calibrated using a standard weight. Scales were placed on a hard, flat surface, and triathletes were weighed in swimming costumes or in some cases swimming costumes and light clothing (wetsuits, shorts, T-shirts). In the triathletes wearing light clothing, the pre-race body weight was adjusted by subtracting an average weight of the clothing items (calculated as the mean weight from a sample of wetsuits, shorts, or T-shirts) from the recorded weight to account for the weight of the light clothing. The final pre-race body weight was therefore the body weight with a swimming costume.

3.2.5. Immediate post-race body weight measurement and calculations

Immediate post-race body weight and blood samples were obtained from the triathletes. Triathletes reported to a designated research area which was located in the "tunnel" within 70m from the finish line. All the race finishers walked through this area on their way to the recovery area. Using the same electronic scales, post-race body weights were recorded with triathletes wearing running gear but no shoes (they were requested to remove these). It was anticipated that some triathletes would not

remove their shoes, in which case this was noted. In triathletes where post-race weights were recorded with running shoes, this was corrected for by subtracting an average running shoe weight (748g per pair for men and 542g per pair for ladies). These shoe weights were obtained by determining the mean weight of 27 different running shoe models/brands. Post-race body weight was therefore recorded as the body weight with running gear. The percentage change in body weight during the race was calculated as the difference between the post-race and pre-race body weight, divided by the pre-race body weight and expressed as a percentage. This calculation was based on the assumption that percentage body weight change would reflect hydration status. Body Mass Index (BMI) was calculated from the self-reported weight and height (obtained from the pre-race questionnaire), using the formula mass (kg) divided by height $(m)^2$.

3.2.6. Immediate post-race blood sample and biochemical analysis

As previously described, triathletes reported to a designated research area immediately after the race. After post-race body weight was recorded, a post-race blood sample was obtained in a similar fashion to the pre-race blood sample. A 5ml venous sample was obtained from an ante-cubital vein, whilst sitting and within 10 minutes of finishing. This was collected in a lithium heparin Vacutainer tube, immediately centrifuged at 3000 × g for 10 minutes at 4°C and stored at -20°C until final analysis for sodium, potassium and chloride concentrations as described above. The absolute changes in serum electrolyte concentrations during the race were calculated as the difference between the post-race and pre-race values. The

absolute change was also divided by the pre-race concentration and expressed as a percentage.

3.2.7. Post race questionnaire

An abbreviated post-race questionnaire was sent by email to all the all 399 subjects who gave consent to participate in the study, within 7 days following the event. In a first email to all the triathletes, they were asked whether or not they had experienced any EAMC during or within 6 hours after the race. Two hundred and seventy-four (68.7%) of the 399 of the triathletes replied to this first post-race email question. Of these, 62 triathletes indicated that they experienced cramps during or immediately after the race, while 212 triathletes did not experience any cramping. There was no response from 103 triathletes and 22 emails were returned to sender - presumably due to an incorrect email address.

A second email questionnaire (Appendix 6) was then sent to those 62 triathletes who reported that they did experience cramps during or immediately after the race. In this email, further details about their cramping during or after the race was requested. Triathletes were specifically asked to answer questions related to the nature and severity of the cramps, the specific leg of the triathlon in which the cramps occurred, and how these cramps were treated. Over 90% (56/62) of the triathletes completed the second component of the post-race email questionnaire.

Of the 56 triathletes who responded with details of their cramps during the race, 43 also completed both the triathlon and the full pre-race questionnaire. Complete pre-

and post-race data on cramping was therefore available in 43 triathletes, and these represent the final cramping (CR) group. Similarly, of the 212 athletes that reported no cramping during the event, 166 had also completed both the triathlon and the pre-race questionnaire, and these represent the final non-cramping control (NC) group.

3.2.8. Environmental conditions on race day

Data on the weather conditions on race day were obtained from the South African Weather Service. The average temperature during the race was 20°C (maximum temperature of 21°C, minimum temperature of 19°C). The average relative humidity during the race was 70%, and the average wind speed was 37 km/h.

3.2.9. Statistical analysis of data

Data were analysed with the STATISTICA version 7.0 (StatSoft Inc., Tulsa, OK, USA) and GraphPad InStat version 2.05a (GraphPad Software, San Diego, CA, USA) statistical programs. Any significant differences between the characteristics of the triathlete groups were determined by a one-way analysis of variance (ANOVA), Pearson chi-square (χ^2) analysis, a Fisher's exact test or a Monte Carlo analysis. When the overall F-value was significant, a Tukey's honest significance *post hoc* test was used to determine specific differences. Once significant differences in the characteristics of the triathlete groups were identified, these categorical and continuous variables were used in a Logit linear and non-linear regression model, to determine factors which best predicted EAMC during the Ironman triathlon. Statistical significance was accepted when $p<0.05$.

3.3. Results

3.3.1.Subject and cramping characteristics

The physical characteristics of the 43 cramping (CR) and 166 non-cramping (NC) triathletes are depicted in Table 3.1. There were no significant differences between the two groups with respect to age, height, self-reported normal body weight, body mass index (BMI) and gender. There was however a trend that the percentage of males was greater in the CR group (p = 0.089).

Table 3.1. General characteristics of the non-cramping (NC) and cramping (CR) triathletes who completed the 2006 South African Ironman Triathlon.

	NC group (n=166)	CR group (n=43)	p-value
Age (years)	38.5 ± 8.9 (158)	37.8 ± 7.3 (39)	0.638
Height (cm)	178.8 ± 8.1 (149)	178.5 ± 9.8 (39)	0.882
Weight (kg) [a]	75.1 ± 10.9 (159)	76.7 ± 11.2 (42)	0.385
BMI (kg/m^2) [b]	23.5 ± 2.3 (147)	24.0 ± 2.7 (39)	0.230
Gender (% males)	82.5 (166)	93.0 (43)	0.089

Except for gender which is expressed as a frequency (%), values are expressed as average ± standard deviation. The number of subjects (n) is in parentheses.
[a] Weight is the athletes self-reported normal weight.
[b] Body mass index (BMI) is calculated as weight (kg) divided by height (m) squared.

Eight (18.6%), 13 (30.2%), 31 (72.1%) and 17 (39.5%) of the triathletes reported that they cramped either once or multiple times during the swim leg, cycle leg, run leg and/or 6 hour immediately after the triathlon, respectively (Figure 3.1A). The majority of the triathletes (n=29, 70.7%) reported experiencing only mild (less than 5 minutes and the triathlete was able to continue exercising) muscle cramps, while only 9 (22.0%) and 3 (7.3%) reported expediency moderate (5-15 minutes and the triathlete was able to continue exercising) or severe (greater than 15 minutes or if the triathlete had to stop exercising) muscle cramps, respectively (Figure 3.1B). The average duration of these cramps was 12.0 ± 31.8 min (n=34) and ranged from 0.1 to 180 min. The muscle groups that cramped and the severity of the cramps are summarised in Figure 3.1C. Ninety-five % of the reported cramps were either in the triathlete's calves, hamstrings, quadriceps or feet. The associated symptoms, signs and medical attention required by triathletes who experienced cramping is depicted in Figure 3.1D. None of the athletes sought medical attention or were confused or comatose as a result of experiencing muscle cramps. The majority of triathletes however reported that their muscles were "tired". Six triathletes who experienced cramping reported that they had dark urine. The treatments used by the athletes to relieve the cramping are summarised in Figure 3.1E. The majority of the triathletes stretched the muscle to relieve the cramping. A variety of other treatments were also used by the triathletes.

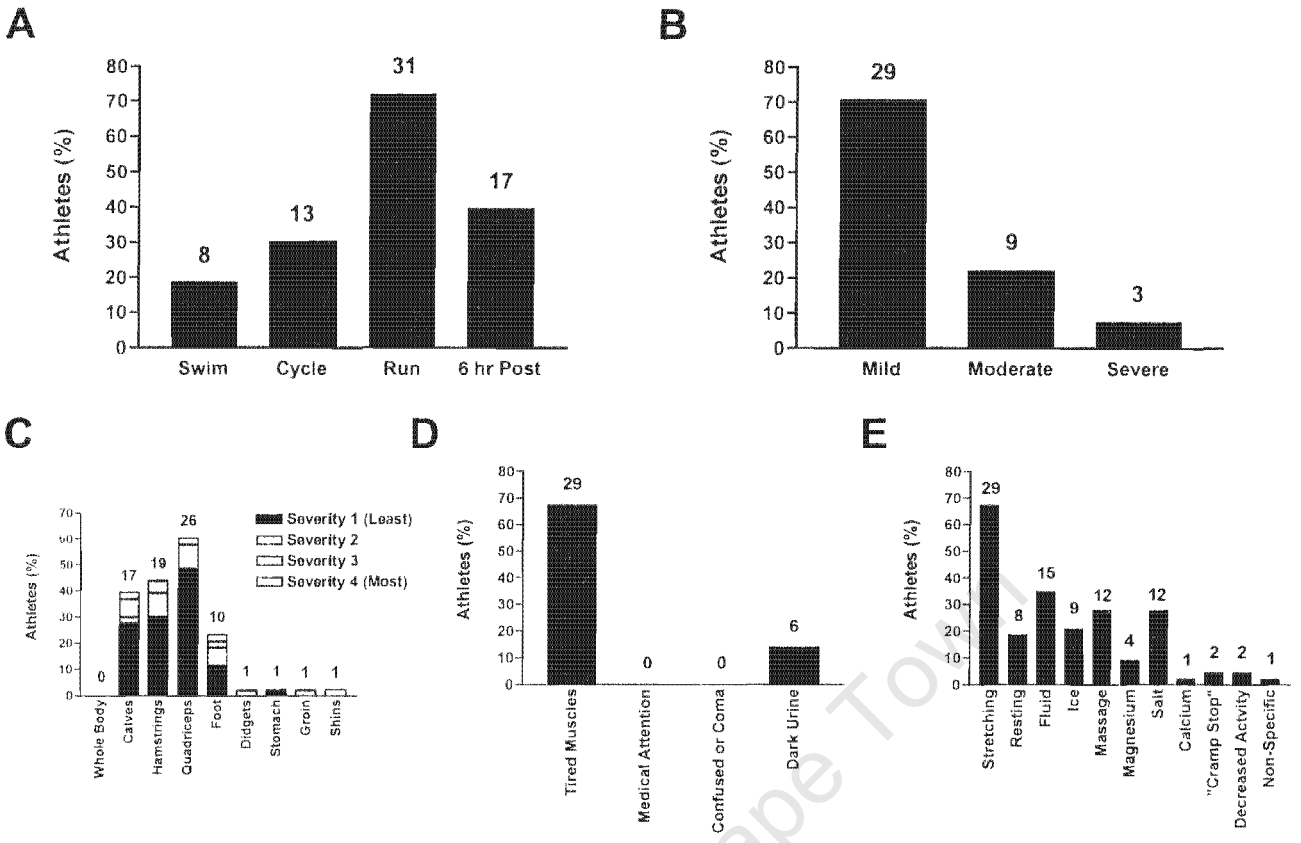

Figure 3.1.: General characteristics of the reported cramping experienced by the triathletes during or within 6 hours after the Ironman Triathlon

(A) The relative number of triathletes who reported experiencing muscle cramps during the swim, cycle, run and/or within 6 hours immediately after (6 hr Post) the triathlon. **(B)** The relative number of triathletes who reported experiencing mild (less than 5 minutes and the triathlete was able to continue exercising) moderate (5-15 minutes and the triathlete was able to continue exercising) or severe (greater than 15 minutes or if the triathlete had to STOP exercising) muscle cramps during or immediately after the triathlon. **(C)** The relative number of triathletes who reported experiencing whole body or specific muscle group cramps. The severity, from the least severe (1) to the most serve (4), of the cramping is also indicated. **(D)** Associated symptoms, signs and medical care **(E)** The relative number of triathletes who reported using the specific treatment to relieve the cramping.
The number of observation (n) is indicated above each bar.

3.2.2. Performance and training history

The self-predicted and actual Ironman performance times for the swimming, cycling and running legs, as well as, the overall predicted and actual times in both the CR and the NC groups is depicted in Table 3.2. The self-predicted cycle-leg times ($p=0.027$), run-leg times ($p=0.018$) and overall times ($p=0.016$) were on average

significantly faster in the CR group. Similarly, the actual race day cycle times (p=0.017) and overall finishing times (p=0.025) were also on average significantly faster in the CR group. There was, however, a trend towards a faster run-leg time during the race in the CR group (p=0.069). There were no significant differences between the predicted and actual swim-leg times between the two groups. In addition, both the NC and CR triathletes completed each leg and the overall triathlon on average slower than their predicted times. Since there was a tendency for their to be more male triathletes in the CR group, the predicted and actual performance times were re-analyzed and similar results were obtained when co-varied for gender (Table 3.2.).

The 209 triathletes recruited for this study were significantly slower for the swim-leg (88 ± 16 min, range 56 - 139 vs. 86 ± 16 min, range 54 - 146; p=0.020), run-leg (294 ± 53 min, range 184 - 481 vs. 286 ± 50 min, range 168 - 481; p=0.025) and the overall (788 ± 95 min, range 522 - 1011 vs. 772 ± 97 min, range 516 - 1021; p=0.026) times of the triathlon when compared to the entire field of 947 competitors. There was, however, no significant differences in the cycle-leg times between the study participants (405 ± 40 min, range 282 – 514) and the entire field (401 ± 44 min, range 282 – 529; p=0.215). There were also no significant differences in the gender distribution (p=0.746), the age-group categories distribution (p=0.479) or the distribution of the triathletes that competed the triathlon during every 30-minute periods (P=0.798) between the groups.

Table 3.2.: The predicted, as reported in the pre-race questionnaire, and actual performance times of the non-cramping (NC) and cramping (CR) triathletes during the 2006 South African Ironman Triathlon

	NC group (n=166)	CR group (n=43)	p-value	Co-varied p-value [a]
Predicted Swim Time (min)	86.2 ± 30.6 (160)	78.8 ± 15.2 (42)	0.129	0.141
Predicted Cycle Time (min)	385.5 ± 45.5 (160)	368.8 ± 34.0 (42)	0.027	0.067
Predicted Run Time (min)	282.8 ± 48.5(159)	263.5 ± 38.9 (42)	0.018	0.025
Predicted Overall Time (min)	762.4 ± 91.7 (157)	723.9 ± 84.9 (41)	0.016	0.033
Actual Swim Time (min)	89.1 ± 15.9 (164)	85.8 ± 16.8 (43)	0.225	0.275
Actual Cycle Time (min)	408.7 ± 40.2 (164)	392.3 ± 38.9 (43)	0.017	0.041
Actual Run Time (min)	297.9 ± 52.1 (165)	281.4 ± 53.9 (43)	0.069	0.083
Actual Overall Time (min)	795.8 ± 93.4 (166)	759.5 ± 95.8 (43)	0.025	0.042
Swim Time (% Predicted) [b]	106.8 ± 16.3 (159)	110.0 ± 12.4 (42)	0.235	n.d.
Cycle Time (% Predicted) [b]	106.4 ± 8.9 (159)	106.6 ± 5.2 (42)	0.926	n.d.
Run Time (% Predicted) [b]	106.0 ± 14.4 (159)	107.3 ± 12.0 (42)	0.585	n.d.
Overall Time (% Predicted) [b]	104.8 ± 8.5 (157)	105.5 ± 6.3 (41)	0.598	n.d.

Values are expressed as average ± standard deviation, with the number of subjects (n) in parentheses.
[a] Co-varied for gender.
[b] Actual times expresses relative to the predicted split and overall times.
n.d., not determined.

The previous overall and recent triathlon and running performances of the CR and NC groups are depicted in Table 3.3. There were no significant differences in any of the parameters between the two groups, indicating that both groups were similarly matched for previous performances (from sprint triathlons to Ironman triathlon distances and from 5km to ultra-marathon running). However, in the 15 weeks prior to the race, triathletes in the CR group had on average significantly faster standard marathon (42.2 km) running times (p=0.042) compared with those in the NC group.

Since only a sub-set of the triathletes completed this section of the questionnaire, the personal best times were re-analyzed co-varying for age and gender. When co-varied for age and gender, there were no significant differences in any of the overall or recent triathlon and running performances of the NC and CR groups (Table 3.3.).

Except for the year in which the triathletes ran their first half marathon (NC during 1994 and CR during 1997, p=0.041), both groups of triathletes started competing in the various triathlon and running disciplines during the same year and have also competed in a similar number of events in each discipline (data not shown). In addition, the NC (3.8 ± 4.3, n=108, range 0 - 25) and CR (4.2 ± 3.7, n=31, range 0 - 17) groups have also competed in a similar number of standard triathlons during the last 2 years (p=0.707).

Table 3.3.: Triathlon (sprint, standard, half-Ironman and Ironman) and road running (5 km, 10 km, 21.1 km, 42.2 km and ultra-marathons) personal best times (PB) and best times achieved over the last 12 months or 15 weeks of the non-cramping (NC) and cramping (CR) triathlete groups

	NC group (n=166)	CR groups (n=43)	p-value	Co-varied p-value [a]
Sprint PB (min)	74.5 ± 16.4 (93)	73.4 ± 15.7 (28)	0.734	n.d.
Standard PB (min)	145.8 ± 26.9 (86)	144.1 ± 29.1 (29)	0.784	n.d.
Half Ironman PB (min)	335.4 ± 42.2 (95)	323.0 ± 51.3 (29)	0.191	n.d.
Ironman PB (min)	756.0 ± 103.9 (61)	741.4 ± 76.6 (25)	0.528	n.d.
Sprint 12 Months PB (min)	78.6 ± 19.0(64)	79.1 ± 19.3 (15)	0.928	0.766
Standard12 Months PB (min)	152.8 ± 27.8 (64)	141.9 ± 36.4 (18)	0.177	0.510
Half Ironman 12 Months PB (min)	342.3 ± 41.8 (69)	327.9 ± 45.3 (18)	0.204	0.478
Ironman 12 Months PB (min)	785.6 ± 106.6 (47)	745.3 ± 80.0 (21)	0.127	0.743
5 km PB (min)	19.9 ± 3.3 (91)	19.4 ± 3.0 (26)	0.477	n.d.
10 km PB (min)	42.2 ± 6.0 (127)	42.1 ± 6.5 (36)	0.929	n.d.
21.1 km PB (min)	95.2 ± 14.4 (133)	96.3 ± 15.8 (36)	0.697	n.d.
42.2 km PB (min)	210.9 ± 29.6 (110)	209.0 ± 29.3 (29)	0.761	n.d.
Two Oceans PB (min)	310.9 ± 45.6 (61)	308.2 ± 52.6 (15)	0.841	n.d.
Comrades PB (min)	554.6 ± 69.8 (69)	578.2 ± 91.4 (14)	0.281	n.d.
5 km 15 weeks PB (min)	21.9 ± 4.3 (42)	20.5 ± 3.0 (10)	0.341	0.317
10 km 15 weeks PB (min)	45.7 ± 5.6 (60)	46.8 ± 6.8 (13)	0.558	0.459
21.1 km 15 weeks PB (min)	104.7 ± 15.4 (74)	102.9 ± 14.0 (18)	0.645	0.798
42.2 km 15 weeks PB (min)	238.2 ± 49.4 (39)	203.2 ± 11.7 (9)	0.042	0.103

Values are expressed as average ± standard deviation, with the number of subjects (n) in parentheses.
PB - personal best time; n.d. - not determined; Comrades - the annual Comrades 89 km ultra-marathon run between Pietermaritzburg and Durban in South Africa; Two Oceans - 56 km ultra-marathon run in Cape Town, South Africa.
[a] Co-varied for age and gender.

Table 3.4.: The swimming, cycling, running and/or total training frequency, distances and durations for the 1 and 15 week period before the Ironman Triathlon of the non-cramping (NC) and cramping (CR) triathletes

	NC group (n=166)	CR group (n=43)	p-value
Training Frequency (days/wk)	5.7 ± 0.9 (155)	5.9 ± 1.0 (37)	0.189
Swim Time 15 week (min/wk)	185 ± 77 (155)	191 ± 100 (39)	0.675
Cycle Time 15 week (min/wk)	489 ± 182 (155)	495 ± 169 (39)	0.846
Run Time 15 week (min/wk)	284 ± 104 (143)	315 ± 105 (38)	0.116
Total Time 15 week (min/wk)	955 ± 259 (141)	1015 ± 287 (36)	0.220
Swim Dist 15 week (km/wk)	6.5 ± 3.2 (158)	6.9 ± 3.6 (37)	0.457
Cycle Dist 15 week (km/wk)	216 ± 85 (154)	230 ± 82 (37)	0.389
Run Dist 15 week (km/wk)	46 ± 17 (153)	51 ± 13 (36)	0.126
Total Dist 15 week (km/wk)	269 ± 92 (151)	295 ± 85 (35)	0.137
Swim Time 1 week (min/wk)	63 ± 58 (158)	71 ± 55 (41)	0.450
Cycle Time 1 week (min/wk)	155 ± 137 (155)	145 ± 112 (38)	0.667
Run Time 1 week (min/wk)	77 ± 64 (153)	78 ± 58 (40)	0.959
Total Time 1 week (min/wk)	299 ± 216 (150)	295 ± 187 (38)	0.924
Swim Dist 1 week (km/wk)	2.2 ± 1.9 (158)	2.5 ± 1.6 (40)	0.296
Cycle Dist 1 week (km/wk)	64 ± 54 (156)	69 ± 54 (40)	0.640
Run Dist 1 week (km/wk)	13 ± 11 (150)	14 ± 11 (38)	0.634
Total Dist 1 week (km/wk)	78 ± 56 (148)	85 ± 63 (38)	0.522

Values are expressed as average ± standard deviation, with the number of subjects (n) in parentheses.

The training frequency and volume during the 1 week before and the 15-week period before the Ironman Triathlon, are depicted in Table 3.4. There were no significant differences in training frequency or volume (distances and durations) for the various disciplines, between the CR and the NC groups.

There were no significant differences in the average cycling speeds of the NC and CR groups, while training during the 15 weeks ($p=0.127$) and 1 week ($p=668$) prior to the triathlon, as well as during a race over 80 km during the 15 week period ($p=0.539$). The average distance of the cycling race was 107 ± 25 km ($n=123$), ranging from 80 to 200 km, and 105 ± 22 km ($n=32$), ranging from 80 to 180 km, for the NC and CR groups, respectively ($P=0.660$). When the cycling speeds were expressed relative to their actual cycling speed during the triathlon, there were no significant difference in the groups relative speeds while training during the 15 weeks ($p=0.464$) or 1 week ($p=0.735$) prior to the triathlon (Figure 3.2B). The triathletes, however, in the CR group cycled on average relatively faster during the Ironman triathlon than those in the NC group when compared to their personal best time over a race longer than 80 km in the 15 weeks prior to the triathlon ($p=0.042$ and $p=0.031$ when co-varied for the race distance). There were no significant differences in the absolute (Figure 3.2C; $p\geq0.697$)) or relative (Figure 3.2D; $p\geq0.350$) running speeds while training and during a half-marathon during the weeks leading up to the Ironman Triathlon.

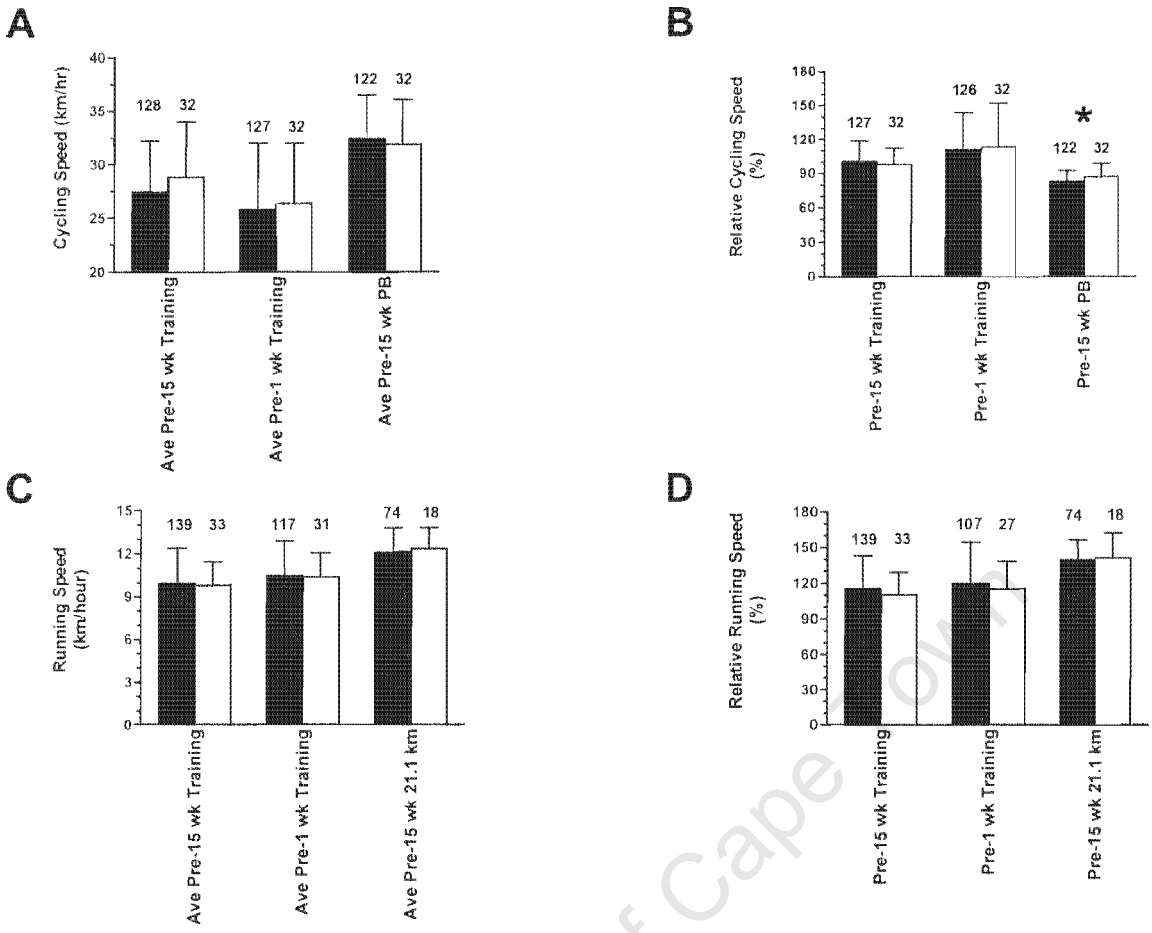

Figure 3.2.: The absolute (A and C) and relative (B and D) cycling (A and B) and running (C and D) training and racing speeds of the non-cramping (black bars) and cramping (clear bars) triathletes prior to the triathlon

The relative cycling and running speeds are expressed relative to their actual cycling and running speeds during the Ironman Triathlon. The number of subjects (n) is indicated above each bar. The asterisks represents $p<0.05$.

3.2.3. Serum electrolyte and weight changes

The pre- and post-race, as well as, the absolute and relative changes in serum electrolyte concentrations in the CR and NC groups are depicted in Table 3.5. There were no significant differences in the pre-race, post-race or changes in serum sodium, potassium and chloride concentrations between the groups.

Table 3.5.: Pre- and post-race, as well as the absolute and relative changes in the serum electrolyte concentrations in the non-cramping (NC) and cramping (CR) triathletes

	NC group (n=166)	CR group (n=43)	p-value
Pre-race [Na^+] (mmol/L)	139.8 ± 1.8 (155)	139.8 ± 1.5 (38)	0.982
Post-race [Na^+] (mmol/L)	140.2 ± 3.4 (124)	139.6 ± 2.5 (33)	0.287
Absolute Change [Na^+] (mmol/L)	0.5 ± 3.7 (124)	-0. 2 ± 2.5 (33)	0.298
Relative Change [Na^+] (%)	0.4 ± 2.6 (124)	-0.1 ± 1.9 (33)	0.836
Pre-race [K^+] (mmol/L)	4.17 ± 0.31 (155)	4.12 ± 0.21 (37)	0.396
Post-race [K^+] (mmol/L)	4.29 ± 0.46 (122)	4.20 ± 0.37 (31)	0.330
Absolute Change [K^+] (mmol/L)	0.09 ± 0.48 (122)	0.07 ± 0.39 (30)	0.808
Relative Change [K^+] (%)	2.5 ± 11.1 (122)	1.9 ± 9.6 (30)	0.766
Pre-race [Cl^-] (mmol/L)	101.7 ± 1.7 (155)	101.6 ± 1.9 (38)	0.662
Post-race [Cl^-] (mmol/L)	100.7 ± 2.5 (106)	100.5 ± 2.1 (31)	0.719
Absolute Change [Cl^-] (mmol/L)	-0.9 ± 3.0 (106)	-1.0 ± 2.8 (31)	0.803
Relative Change [Cl^-] (%)	-0.9 ± 2.9 (106)	-1.0 ± 2.7 (31)	0.860

Values are expressed as average ± standard deviation, with the number of subjects (n) in parentheses.

The pre- and post-race body weights and the absolute and relative changes in body weights in the CR and the NC groups are depicted in Table 3.6. There were no significant differences in the pre-race, post-race or changes in body weights during the race between the groups.

Table 3.6.: Pre- and post-race, as well as the absolute and relative changes in body weights in the non-cramping (NC) and cramping (CR) triathletes

	NC group (n=166)	CR group (n=43)	p-value
Pre-race Weight (kg)	76.7 ± 11.1 (151)	78.1 ± 12.1 (41)	0.470
Post-race Weight (kg)	73.9 ± 10.6 (154)	74.9 ± 10.3 (40)	0.610
Absolute Weight Change (kg)	-2.4 ± 1.5 (139)	-2.2 ± 1.5 (38)	0.362
Relative Weight Change (%)	-3.1 ± 1.9 (139)	-2.8 ± 1.8 (38)	0.252

Values are expressed as average ± standard deviation, with the number of subjects (n) in parentheses.

3.2.4. Estimated fluid intake and strategy

The predicted fluid intake during the swim, cycle and running legs of the Ironman Triathlon as well as the strategy employed by the triathletes to determine fluid intake during the competition in the CR and the NC groups is depicted in Table 3.7 and Figure 3.3. Triathletes in the CR and the NC groups estimated similar volume fluid intakes and predicted similar fluid intake strategies for the event. These observations did not alter when co-varied for performance times.

Table 3.7.: Estimated volume fluid intake during the swim, cycle and running legs of the Ironman Triathlon, as well as the strategy employed by the triathletes to determine fluid intake during the event in the non-cramping (NC) and cramping (CR) groups

	NC group (n=166)	CR group (n=43)	p-value	Co-varied p-value
Estimated Swim Volume (ml)	28 ± 131 (155)	30 ± 139 (41)	0.906	0.865 [a]
Estimated Cycle Volume (ml)	4211 ± 1575 (155)	4165 ± 1488 (41)	0.836	0.791 [b]
Estimated Run Volume (ml)	2693 ± 1385 (148)	2895 ± 1516 (41)	0.419	0.267 [c]
Thirst [d]	21.0 (34)	23.8 (10)		
Predetermined [d]	22.2 (36)	21.4 (9)		
Tolerable [d]	11.7 (19)	11.9 (5)		
Weight Loss [d]	2.5 (4)	0.0 (0)	0.915	n.d.
Predetermined and Thirst [d]	32.7 (53)	31.0 (13)		
Predetermined and Tolerable [d]	6.2 (10)	4.8 (2)		
Various Other Combinations [d]	3.7 (6)	7.2 (3)		

Except for the estimated volumes which are expressed as averages ± standard deviations, values are expressed as frequencies (%). The number of subjects (n) is in parentheses.
n.d. - not determined.
[a] Co-varied for predicted swim time.
[b] Co-varied for predicted cycle time.
[c] Co-varied for predicted run time.
[d] The triathletes reported that they planned to drink either to thirst, to a predetermined rate, what is tolerable, to replace weight loss or various combinations of these options.

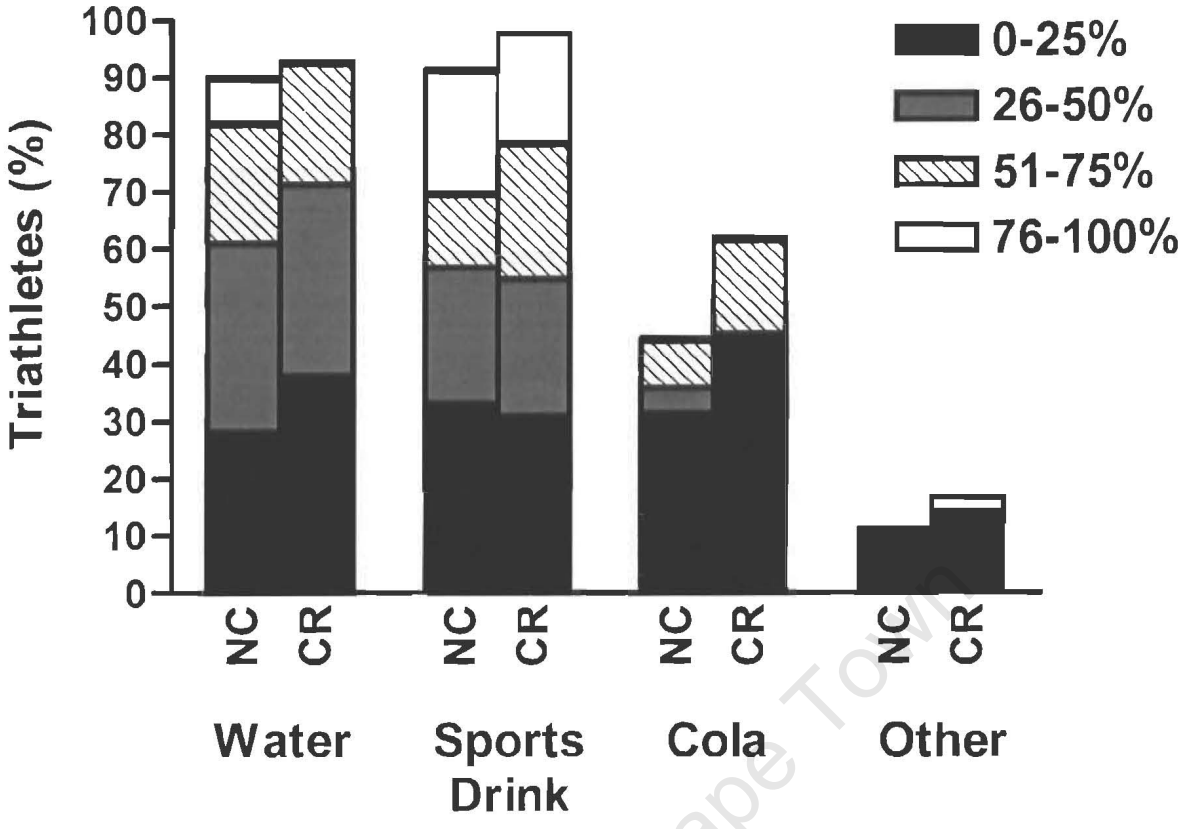

Figure 3.3.: The self-reported predicted fluid intake (water, sports drink, cola or other), expressed as a percentage of total fluid intake for the NC and the CR groups. There was no significant difference between groups (p=0.641).

3.2.5. Cramping history

The triathletes personal exercise-associated muscle cramping (EAMC) history and a family history of EAMC and nocturnal cramping, in both the CR group and the NC group, is shown in Table 3.8. Triathletes in the CR group, had a significantly higher reported past history of EAMC ($p<0.001$) compared with the NC group. There was no significant difference in the prevalence of family history of EAMC or nocturnal cramping between the groups.

Table 3.8.: Cramping and family history of cramping in the non-cramping (NC) and cramping (CR) triathletes

	NC group (n=166)	CR group (n=43)	p-value
Previous EAMC (% yes)	45.5 (165)	82.9 (41)	<0.001
Family History EAMC (% yes)	23.7 (156)	32.5 (40)	0.351
Family History Nocturnal Cramps (% yes)	22.9 (157)	26.2 (42)	0.812

Values are expressed as a frequency (%) with the number of subjects (n) in parentheses.
EAMC - exercise-associated muscle cramps.

In Table 3.9., the details of the number of cramps experienced in past races and training sessions is depicted. The specific leg of the triathlon, in which cramping usually occurs, for the CR group, and the NC group (that reported a past history of cramping but did not experience cramping during the 2006 Ironman) is also depicted. There was no significant difference in the number of years triathletes with a history of cramping in both the NC and CR groups experienced muscle cramping during exercise (p=0.194). Similarly, there were no significant differences in the number of triathletes in each group that experienced EAMC during the last year (p=0.232). Triathletes in the CR group, however, reported a significantly greater mean number of cramps in their last 10 races (p=0.003), but not the last 10 training sessions (p=0.814), compared to the triathletes in the NC group with a past history of cramping. They also reported a greater frequency of cramping during running (p=0.030), and greater frequency of whole body cramping (p=0.006), compared to the triathletes in the NC group. In both groups, cramping is experienced in the last quarter or immediately after the race in > 80% of triathletes. The majority of triathletes also reported that they experience mild muscle cramps which usually last less than 5 minutes and the triathlete was able to continue exercising.

The NC triathletes with a past history of cramping reported cramping in the following muscles; 45 in their calves, 25 in their hamstrings, 32 in their quadriceps, 14 in their feet, 1 in their knee, 1 in their stomach, 1 in their abductors, 1 in their inside thigh and 1 was undefined. The site of cramping in the CR group was as follows; 20 in their calves, 16 in their hamstrings, 25 in their quadriceps, 14 in their feet, 2 in their inner thighs, 1 in their fingers, 1 in their shins, 1 in their abdominals and 1 was undefined.)

3.2.6. Flexibility training

The flexibility training habits of both the CR and the NC groups are depicted in Table 3.10. There were no significant differences between the two groups with respect to frequency or duration of stretching, total weekly stretching time, and the muscle groups that were stretched.

Table 3.9.: Cramping history and description in the non-cramping (NC) triathletes with a history of cramping, but did not report cramping during the Ironman Triathlon, and the cramping (CR) triathletes

	NC group with a past history of cramping (n=75)	CR group (n=43)	p-value
Cramping (years)	6.1 ± 7.5 (48)	8.5 ± 7.7 (26)	0.194
Cramped last 12 Months (% Yes)	70.8 (72)	81.8 (33)	0.232
No. of Cramps in Last 10 Races	1.1 ± 1.5 (67)	2.9 ± 4.5 (32)	0.003
No. of Cramps in Last 10 Training Sessions	1.2 ± 2.1 (65)	1.3 ± 1.4 (32)	0.814
Cramp while Swimming (%)	38.6 (70)	48.5 (33)	0.461
Cramp while Cycling (%)	47.1 (70)	54.4 (33)	0.624
Cramp while Running (%)	54.3 (70)	78.8 (33)	0.030
1st Cramp during 1st Quarter (%)	3.0 (67)	3.0 (34)	0.543
1st Cramp during 2nd Quarter (%)	3.0 (67)	9.1 (34)	0.428
1st Cramp during 3rd Quarter (%)	10.4 (67)	15.2 (34)	0.765
1st Cramp during 4th Quarter (%)	59.7 (67)	69.7 (34)	0.574
1st Cramp during Post-race (%)	23.9 (67)	30.3 (34)	0.719
No Pattern for 1st Cramp (%)	17.9 (67)	12.1 (34)	0.609
Mild Cramping (%) [b]	79.4 (68)	59.4 (32)	0.062
Moderate Cramping (%) [b]	17.6 (68)	31.3 (32)	0.203
Severe Cramping (%) [b]	2.9 (68)	9.4 (32)	0.438
Duration of Cramps (min)	3.9 ± 8.6 (63)	3.5 ± 3.5 (27)	0.803
Whole Body Cramps (%)	2.9 (69)	18.8 (32)	0.006
Associated symptoms/signs (%) [a]	7.2 (69)	3.0 (33)	0.692

Values are expressed as averages ± standard deviations or as frequencies (%). The number of subjects (n) is in parentheses.
[a] Admitted to hospital, none; confused or coma, 1 NC; dark urine, 4 NC and 1 CR.
[b] mild cramps, <5 minutes and able to continue exercising; moderate cramps, 5-15 minutes and able to continue exercising; severe cramps, >15 minutes or had to STOP exercising.

Table 3.10.: Flexibility training history of the non-cramping (NC) and cramping (CR) triathletes

	NC group (n=166)	CR group (n=43)	p-value
Stretch Training (% yes)	58.5 (164)	65.1 (43)	0.433
Frequency (days/wk)	4.0 ± 1.7 (95)	3.8 ± 2.0 (26)	0.621
Frequency (times/day)	1.2 ± 0.8 (91)	1.7 ± 2.8 (25)	0.130
Duration (sec/stretch)	24 ± 12 (93)	24 ± 12 (30)	0.808
No. of Times each Muscle Group Stretched	2.2 ± 1.1 (96)	2.1 ± 1.1 (30)	0.632
Total Duration (min/wk) [a]	5.1 ± 4.9 (83)	4.8 ± 7.9 (24)	0.857
Stretch before Exercise (%)	40.8 (98)	51.7 (29)	0.298
Stretch during Exercise (%)	24.5 (98)	14.3 (28)	0.252
Stretch after Exercise (%)	90.8 (98)	89.3 (28)	0.808
Soleus (%) [b]	76.0 (96)	85.7 (28)	0.406
Gastrocnemius (%) [b]	89.6 (96)	96.4 (28)	0.457
Groin (%) [b]	60.4 (96)	71.4 (28)	0.401
Hamstring (%) [b]	97.9 (96)	96.4 (28)	0.804
Quadriceps (%) [b]	89.6 (96)	75.0 (28)	0.097
Upper Body (%) [b]	62.5 (96)	53.6 (28)	0.528

Values are expressed as averages ± standard deviations or as frequencies (%). The number of subjects (n) is in parentheses.
[a] The total weekly stretching time (min/week) was calculated as duration of stretch (min) X number of times each muscle group was stretched per day (number)X stretch sessions per day (number) X days of stretching per week (number)
[b] Expressed as a percentage of triathletes who reported that they perform flexibility training.

3.2.7. Past history of EAMC

The 166 triathletes who did not cramp during the Ironman Triathlon (NC group) were divided into two sub-groups, those with no history of EAMC (n=91) and those with a past history of EAMC (n=75), and compared to the CR group. As shown in Table

3.11, the NC group with a past history of EAMC was significantly taller than the NC group with no history of EAMC (p=0.018). There was also significant difference in the gender distribution between the three groups (p=0.020).

The CR group completed the cycle leg of the triathlon on average significantly faster than the NC group with no history of EAMC (p=0.017). There was also a tendency for the relative cycle speed, which was expressed as their actual cycling speed relative to their personal best time in a long distance cycle during the 15 weeks prior to the triathlon, of the CR group to be faster than the NC groups (p=0.090).

Table 3.11.: General, performance and training characteristics, as well as the estimated drinking volumes, serum electrolyte concentrations, weights and weight changes of the non-cramping (NC) triathletes with no history of cramping, the NC triathletes with a past history of cramping and cramping (CR) triathletes who completed the 2006 South African Ironman Triathlon

	NC group with no history of EAMC (n=91)	NC group with a past history of EAMC (n=75)	CR group (n=43)	p-value	Co-varied p-value [d]
Age (years)	37.6 ± 7.7 (85)	39.6 ± 10.0 (73)	37.8 ± 7.3 (39)	0.638	n.d.
Height (cm)	177.1 ± 8.7 (82) [a]	180.8 ± 7.0 (67) [a]	178.5 ± 9.8 (39)	[a] 0.018	n.d.
Pre-race Weight (kg)	75.6 ± 12.0 (83)	78.0 ± 9.8 (68)	78.1 ± 12.1 (41)	0.334	n.d.
BMI (kg/m^2) [c]	23.3 ± 2.5 (81)	23.7 ± 2.1 (66)	24.0 ± 2.7 (39)	0.329	n.d.
Gender (% males)	76.9 (91)	89.3 (75)	93.0 (43)	0.020	n.d.
Actual Swim Time (min)	89.6 ± 14.8 (89) [b]	88.5 ± 16.3 (75)	85.8 ± 16.8 (43) [b]	0.431	[b] 0.599
Actual Cycle Time (min)	412.5 ± 38.8 (89) [b]	404.2 ± 41.5 (75)	392.3 ± 38.9 (43) [b]	[b] 0.017	[b] 0.040
Actual Run Time (min)	297.3 ± 51.7 (90) [b]	298.5 ± 53.0 (75)	281.4 ± 53.9 (43) [b]	0.189	[b] 0.105
Actual Overall Time (min)	800.0 ± 90.7 (91) [b]	791.2 ± 96.9 (75)	759.5 ± 95.8 (43) [b]	[b] 0.055	[b] 0.049
Relative Cycle Speed (%) [e]	83.4 ± 9.3 (66)	83.0 ± 9.7 (56)	87.2 ± 11.9 (32)	0.090 [f]	n.d.
Half Ironman 12 Months PB (min)	347 ± 48 (37)	336 ± 32 (32)	328 ± 45 (18)	0.250	n.d.
Ironman 12 Months PB (min)	790 ± 108 (22)	782 ± 108 (25)	745 ± 80 (21)	0.305	n.d.
21.1 km 15 weeks PB (min)	105 ± 14 (41)	105 ± 14 (33)	103 ± 14 (18)	0.896	n.d.
Total Training Time 15 wk (min/wk) [g]	971 ± 273 (79)	934 ± 240 (62)	1015 ± 287 (36)	0.338	n.d.
Total Training Dist 15 wk (km/wk) [g]	270 ± 98 (84)	269 ± 85 (67)	295 ± 85 (35)	0.331	n.d.
Total Training Time 1 wk (min/wk) [g]	310 ± 246 (83)	284 ± 172 (67)	295 ± 187 (38)	0.754	n.d.
Total Training Dist 1 wk (km/wk) [g]	80 ± 63 (80)	75 ± 47 (68)	85 ± 63 (38)	0.706	n.d.
Estimated Cycle Drinking Volume (ml)	4375 ± 1640 (83)	4044 ± 1489 (72)	4165 ± 1488 (41)	0.409	n.d.
Estimated Run Drinking Volume (ml)	2827 ± 1371 (78)	2544 ± 1395 (70)	2895 ± 1516 (41)	0.345	n.d.
Post-race [Na^+] (mmol/L)	140.7 ± 3.0 (67)	139.6 ± 3.8 (57)	139.6 ± 2.5 (33)	0.081	n.d.
Relative Weight Change (%)	-2.9 ± 2.0 (79)	-3.4 ± 1.7 (60)	-2.8 ± 1.8 (38)	0.177	n.d.

Except for gender which is expressed as a frequency, values are expressed as average ± standard deviation. The number of subjects (n) is in parentheses.
[c] Body mass index (BMI) is calculated as the athletes self-reported normal weight (kg) divided by height (m) squared.
[d] Co-varied for gender, height and weight.
[e] The relative cycle speed is the actual speed during the cycle leg of the Ironman Triathlon expressed relative to the triathletes personal best speed in a cycle race. longer than 80 km during the 15 weeks before the triathlon.
[f] co-varied for the length of the cycle race, which ranged from 80 to 200 km.
[g] Total training time and distance during the 15 weeks and 1 week before the triathlon.
EAMC, exercise-associated muscle cramps; PB, personal best; Dist, distance; wk, week; n.d., not determined.

3.2.8. Risk factors for EAMC in triathletes

The results of the regression analysis to determine the independent risk factors for EAMC in Ironman triathletes are presented in Table 3.12. The significant independent risk factors for EAMC in Ironman triathletes were the reported number of cramp episodes in the past 10 races (p=0.011), and overall finishing time for the event (p=0.010). In particular, post race serum sodium concentrations and relative change in body weight (as a measure of hydration) were not risk factors for EAMC in these athletes. In a separate analysis where only two variables were considered, both relative cycling speed (percentage of their personal best cycling speed in the 15 weeks before the Ironman event) (Estimate ± SE = -0.05 ± 0.02, p=0.037), and the number of reported cramps in the last 10 races (Estimate ± SE = -0.39± 0.11, p<0.001) were also significant predictors of EAMC in these triathletes.

Table 3.12.: Regression analysis for the determination of independent risk factors EAMC in Ironman triathletes (SE is Standard Error)

	Level of Effect	Estimate ± SE	Wald Stat	p-value
Gender	male	-0,35 ± 0.42	0.69	0.408
No. of Cramps in Last 10 Races		-0.29 ± 0.11	6.43	0.011
Post-race [Na^+] (mmol/L)		0.10 ± 0.08	1.49	0.222
Relative Weight Change (%)		-0.13 ± 0.13	0.99	0.320
Overall Time (min)		0.01 ± 0.01	6.64	0.010

3.4. Discussion

The main novel finding of this prospective cohort study was that the two independent risk factors for the development of EAMC in Ironman triathletes were a past history of muscle cramping (in particular the number of EAMC reported in the last 10 races) and an overall faster race time during the Ironman triathlon. Triathletes who experienced EAMC predicted faster overall, cycle and run times before the race, and then proceeded to cycle and run faster during the race when compared with non-cramping triathletes that reported similar training and past performance parameters. This study is, to our knowledge, the largest prospective cohort study on EAMC in endurance athletes.

Other significant findings from this study addressed the more "traditional" risk factors for EAMC. In our study we found that 1) there was no difference in the pre- and post race serum electrolyte (sodium and chloride) concentrations, in triathletes who experienced EAMC and those who did not, 2) there was no difference in pre- and post-race body weight (as an indicator of hydration status) in triathletes who experienced EAMC and those who did not, and 3) cramping and non-cramping triathletes did not differ with respect to flexibility training, BMI, age and predicted habitual fluid intake.

In 1997, Schwellnus et al. [6], first proposed that the development of muscle fatigue during exercise, rather than serum electrolyte changes, dehydration, or inherited metabolic abnormalities may be responsible for the development of EAMC during prolonged endurance exercise. This "fatigue" hypothesis was based on the findings that muscle fatigue can lead to an increased neuromuscular "excitability". In support

of this hypothesis, were observations that 1) there is increased spinal reflex activity of the muscle spindle and decreased Golgi tendon organ activity following the development of muscle fatigue in animal experiments [44;45], 2) there is increased baseline electromyographic (EMG) activity in cramping muscle in athletes, which decreases as the athlete recovers from EAMC [9;17], and 3) clinical observations of typical conditions predisposing to EAMC such as development of EAMC towards the end of exercise sessions, and that athletes frequently report muscle fatigue before the onset of EAMC [3;10;11;18].

In animal experimentation where spinal reflex activity was documented during muscle fatigue, it has been shown that there is a net increase in alpha motor activity. This is the consequence of increased muscle spindle firing rate (which stimulates the alpha motor neuron) and a decreased Golgi tendon organ firing rate (which usually inhibits the alpha motor neuron) [44;45]. The exact mechanism by which fatigue effects these changes is not known, and still requires further investigation.

Between bouts of acute cramping, endurance athletes experiencing EAMC, show increased motor neuron activity in the cramp-prone muscles [9;17]. This is reflected by increased EMG activity. Furthermore, muscles that cramp show a greater reduction of their baseline EMG activity during recovery, than those that do not cramp. The reduction in EMG activity in these muscle parallels the recovery from this "cramp-prone" state [17].

There are observational data in marathon runners that also support the premature muscle fatigue hypothesis of EAMC. Cramps in marathon runners were reported to

be preceded by the development of subjective muscle fatigue, and were more likely during high-intensity racing, running longer distances, hill running and subjective poor performance [10;42].

The findings from this study in Ironman triathletes further support the "fatigue" hypothesis of EAMC during endurance events. In this study, the group of cramping athletes predicted significantly faster run, cycle and overall finishing times than those triathletes that did not cramp. These time predictions were made 1 to 3 days before the event. This is despite the fact that both groups of athletes reported similar personal best times and performances, ranging from sprint triathlon events to Ironman distance triathlons and from 5km to ultra-marathon running distances. All-time best performances and recent best performances were similar in the cramping and non-cramping triathletes.

Furthermore, there was also no significant difference between the groups with respect to their training volume or intensity before the Ironman race. Therefore despite the cramping and non-cramping athletes being matched for performance and training parameters pre- race, triathletes in the cramping group predicted significantly faster running, cycling and overall performance times. Studies on other Ironman triathlons have shown that those that performed better had done a significantly greater training volume before the race [56;57]. Both groups of athletes in our study had performed similar amounts of training, yet the cramp group predicted faster times. It can thus be concluded that although both cramping and non-cramping triathletes were similar in ability and preparation, triathletes in the cramping group intended to perform better. This would necessitate racing at a faster pace and subsequently, a

higher intensity. They would thus be extending themselves to a greater degree and be more vulnerable to early fatigue than those with slower predicted times.

Data, which was collected on the actual race day, confirmed that both cycling and overall performance times of the cramping group of triathletes were significantly faster compared with the non-cramping group. Furthermore, there was a trend for the run times to be faster in the cramping group. It therefore appears that triathletes in the cramping group predicted and then subsequently raced at a higher intensity compared with non-cramping triathletes. Although we did not measure relative exercise intensity during the race, it appears that the cramping group exercised at a higher relative intensity during the race compared with the non-cramping group. In support of this was the data showing that triathletes in the cramping group cycled at an increased relative cycling speed compared with triathletes who did not cramp during the race (Figure 3.2B, $p=0.031$).

These findings therefore provide further evidence that the development of muscle fatigue is likely to be an important predictor of the development of EAMC during a triathlon. It is interesting to note that in our study, as in previous studies, the majority of triathletes also reported muscle fatigue to be associated with the development of EAMC, and that most triathletes developed EAMC in the latter part of the race or immediately after the race. Only a small number (n=8) triathletes reported muscle cramping during the swim stage of the event. The mechanism for cramping during swimming may well differ from that during weight-bearing sports, and requires further investigation.

A past history of cramping was also a significant risk factor for EAMC in triathletes. In particular, a history of cramping in the past 10 races, but not training sessions, was strongly associated with EAMC during the Ironman triathlon. However, cramping triathletes did not report a greater frequency of a positive family history of EAMC, or a positive family history of nocturnal cramping. Although speculative, these findings suggest that athletes who have a past history of cramping may not have an inherited genetic component but rather that when exercising at a higher intensity, such as during races, they are more prone to cramping.

The second important finding from our study was that pre- and post-race serum electrolyte (sodium and chloride) concentration changes and body weight changes did not differ between cramping and non-cramping triathletes. Although the precise aetiology of EAMC is not completely understood, our findings confirm those of recently published studies, where there was no relationship between serum electrolyte concentrations, or hydration status, and the development of cramping during endurance events. The hypothesis that serum electrolyte changes, in particular serum sodium changes, cause EAMC is therefore not supported by the findings in this study.

The traditional electrolyte theory is based on the assumption that it is the perturbations of the serum electrolyte concentrations during prolonged endurance exercise that cause muscular cramping. Although numerous recent studies fail to show a clear relationship between EAMC and serum electrolyte abnormalities [8;9;42], this hypothesis persists [12-15].

Early investigators questioned whether losses of sodium, magnesium and chloride were implicated in the propensity for EAMC. The focus of research soon shifted to sodium and, in particular, to the development of hyponatraemia during exercise. In the late1980s Hiller suggested that it was the unreplaced salt losses in sweat, associated with dehydration, that lead to hyponatraemia [19;58]. Subsequently, it has been shown that dehydration is associated with the development of hypernatraemia and that the greater the weight loss during an endurance event, the higher the serum sodium will be [59].

Conversely, hyponatraemia may have a number of different aetiological mechanisms. This should be borne in mind when the occurrence of EAMC is related to serum sodium levels. It has been shown that *severe* hyponatraemia (serum sodium less than 130mmol/l) is invariably caused by fluid overload; either due to excessive hypotonic fluid consumption or inappropriate arginine vasopressin (AVP) secretion. *Mild* hyponatraemia (serum sodium 130-134mmol/l) may have different aetiologies related to profuse sweating in hot climates and needs further research.

According to the Consensus statement of the 1st International Exercise-Associated Hyponatremia Consensus Development Conference in 2005, excessive sodium losses are not thought to be a primary causative mechanism in exercise-associated hyponatremia. [60] The primary factor is an increase in total body water relative to total body exchangeable sodium, resulting in a dilutional hyponatremia. This is either due to excessive consumption of hypo-osmotic fluids or due to inappropriate arginine vasopressin (AVP) secretion. Sodium losses may play a secondary role if there are very high sweat sodium concentrations or high urinary losses. However, these

sodium losses have a much lesser effect than the gross effect of over-hydration. The consensus panel recognizes that further research is needed to elucidate the pathophysiology of hyponatremia in athletes with above average weight losses, larger than normal sweat losses, in hotter environmental conditions and in prolonged events.

The relevance of this to our study on EAMC is that serum values of sodium may not necessarily reflect the plasma volume and hence the hydration status. They also do not necessarily reflect whole body stores of sodium. An athlete, who has only lost a small amount of sodium and water via sweat but has consumed a lot of water, may have hyponatraemia, despite a normal whole body sodium level. In other words, there has been a dilutional effect. Conversely, an athlete who has sweated a great deal and lost a lot of salt and water but has not drunk much replacement fluids, may be dehydrated, with a contracted extracellular volume. The serum sodium may only be mildly decreased or even normal, despite a loss of whole body sodium. This is illustrated by examining the literature on hyponatraemia which relates increases in serum sodium and decreases in plasma volume in studies conducted on endurance athletes 20 to 30 years ago [19;61;62] but the converse, decreases in serum sodium and increases in plasma volume observed in endurance athletes in the last 10 years [63-65]. Interestingly, the dangers of hyponatraemia have recently received more attention.

If the hypothesis that a low sodium concentration in the interstitial space, surrounding the neurons causes them to become irritable and more prone to discharge, and that this causes cramps, then the concept of whole body sodium is important.

"Heat cramps" or "coal miners' cramps" were first described by Brockbank in 1929 [32] and illustrate the basis for the environmental theory on EAMC. However, it has generally been accepted that it is not the actual elevation of core temperature that is related to cramping [66], and that passive heating at rest does not induce cramps. The miners described in Brodbank's paper were subjected to prolonged extreme heat whilst at work and their large sweat rates were far in excess of what is observed in endurance sports today.

The potential deleterious effect of exercising in the heat may lie in the excessive sweating that takes place in these conditions. A great amount of sodium, as well as water, may be lost and may result in a whole body deficit of sodium when simple rehydration is undertaken. Hyponatraemia is a well-recognized condition amongst endurance athletes, but the link with EAMC remains tenuous. Some researchers suggest a distinction between fatigue-induced and heat-related cramps [24]. They propose that fluid and electrolyte replacement during endurance exercise in hot conditions (with high sweating rates) may delay and even prevent EAMC, but that such supplementation in less extreme conditions will have little effect. Our study was conducted in mild environmental conditions.

Furthermore, researchers have conducted experiments to induce muscular fatigue in controlled hot environments and have shown that despite dehydration and hyperthermia, there was very little effect on neuromuscular performance [67].

In a recently published laboratory study, neuromuscular fatigue was induced in a specific muscle group under controlled environmental conditions [24]. In this study, a

specific protocol, designed to induce muscle fatigue, resulted in EAMC in the majority of cases. In this study, it was concluded that although hydration and electrolytes may play a role in the development of EAMC, the constant factor remained local muscle fatigue. In this study it was also shown that by ingesting a combination electrolyte and carbohydrate solution, the incidence of EAMC was not reduced, but the time to onset of EAMC was prolonged. Limitations of this study were that there was no measurement of serum electrolyte concentrations or body weight changes. The duration of exercise was also very short. These findings, however, do not support the hypothesis that fluid and electrolyte replacement, in particular sodium supplementation, can prevent the development of EAMC.

In our study, post-race serum sodium and chloride concentrations of Ironman triathletes remained unchanged when compared with pre-race values and were within clinically normal parameters. More importantly, these post-race serum electrolyte concentrations were not significantly different between the cramping and non-cramping groups. These findings therefore do not support the hypothesis that serum electrolyte changes (sodium and chloride) are associated with the development of EAMC in triathletes. Our findings are similar to those that have been previously reported in ultra-distance runners [8;42], long-distance cyclists [68], and triathletes [9], where no relationship between changes in serum electrolyte concentrations and the development of EAMC was found.

A limitation of our study was that no attempt was made to quantify whole body sodium content, perhaps by measuring urine sodium excretion. A low urinary sodium excretion would indicate enhanced renal sodium re-absorption in response to whole

body depletion. With very high and prolonged sweating rates, athletes may lose a significant amount of sodium. Mere fluid rehydration may induce a relative hyponatraemia. Several studies propose that the serum sodium concentration is protected by movement of sodium from the interstitial compartment into the intra-vascular compartment. Thus, although an athlete may have a normal serum sodium concentration, it has been suggested that whole body sodium may be decreased and this may affect generalized neuromuscular excitability. It is logical to then assume that whole body sodium depletion would lead to whole body cramping. It has been observed that in experimentally induced hyponatraemia at rest, the clinical presentation of cramping is that of generalized skeletal muscle cramping. However, it is important to point out that in the majority of endurance athletes suffering from EAMC, these cramps are localized, and confined to the exercising muscles. In our study, no triathletes with EAMC reported whole body cramping. Furthermore, we have previously shown that EMG activity in the non-cramping muscle of triathletes suffering from EAMC is not increased when compared to the cramping muscle [9;18]. This finding supports the hypothesis that changes in cramping muscles are local and not systemic. Hence, total body sodium depletion resulting in generalized neuromuscular excitability cannot be supported by these findings. We therefore did not study total body sodium changes in these triathletes.

It has been reported that in endurance running events, female athletes and those that run slower are at greater risk for developing hyponatraemia. As has been discussed, in this study we found that it was the faster triathletes that were more likely to cramp. Furthermore, there was no significant difference between male and female triathletes with respect to cramping frequency, in our study.

Another popular hypothesis is that EAMC is associated with dehydration. Similar to the electrolyte theory, this dehydration hypothesis has not been supported by recent studies [8;9]. It has been shown that there is no relationship between the development of EAMC and changes in body weight, plasma volume, blood volume or red cell volume. Within the limitations of accepting these parameters as being a reflection of hydration status, it has been concluded that the hydration status is not related to development of EAMC in endurance athletes [8;9;42].

In our study, we also demonstrated that there was no significant difference between percentage weight changes during the race in the cramping and non-cramping triathletes. There was also no difference between the two groups with respect to self-reported habitual fluid intake (volume and composition). Changes in body weight therefore are not related to development of EAMC in triathletes.

It should be mentioned that although change in body weight, over the course of an event, does reflect a change in the volume of the extracellular fluid compartment and hence hydration status, there are other factors to consider. Rogers et al. (1997) showed that the percentage body weight loss is also largely accounted for by breakdown of endogenous fuel sources and the translocation of water associated with glycogen [69]. In their study, the mean decrease in body weight was 4.6% but loss of extracellular water only accounted for only 1.9%. In our study the non-crampers lost an average of 3.2% relative body weight and the crampers 2.8%. These values are in keeping with other studies. According to Speedy et al. (1999), an athlete needs to lose approximately 4% relative body mass to maintain sodium levels, in the face of

an exercise-induced expansion of plasma volume [41]. This would imply that all our athletes would have experienced a relative dilution of their sodium concentrations. Yet they did not all develop EAMC.

Serum glucose measurements were not recorded in our study but it has previously been shown that by supplementing carbohydrates, together with rehydration fluids, during prolonged exercise, that the time to onset of EAMC can be prolonged. Presumably this is because the carbohydrates delay the onset of neuromuscular fatigue. The actual incidence of cramping remains unchanged though, irrespective of whether or not a carbohydrate-electrolyte beverage is consumed. Carbohydrates may delay fatigue but not prevent it.

It has also been suggested that a low serum magnesium concentration can precipitate muscular cramping during exercise. In this study we did not measure serum magnesium concentrations, as previous reports showed no relationship between serum magnesium concentration and EAMC [9]. However, in this current study a question about magnesium supplements taken during the race was included in the post-race questionnaire. Only 3 athletes reported using magnesium tablets to try to stop their cramps.

Other previously reported possible risk factors for EAMC include higher body mass index (BMI), older age group, longer history of running, family history of cramping and poor flexibility training [10;70]. In our study, we did not find any relationship between these variables and the risk of EAMC. Other researchers suggest that EAMC is associated with subjective muscle fatigue, fast running pace, racing and subjective

poor performance [10]. These predictors support the fatigue hypothesis and also agree with our findings of increased cramping in those who raced harder and faster. There was no correlation between flexibility training habits and EAMC in our study group. It therefore appears that this finding does not support the hypothesis that those athletes who perform regular and consistent stretching exercises, both before and during exercise, are less likely to develop EAMC. It should, however, be noted that both the cramping group and the non-cramping triathletes in our study performed very little stretching. In both groups, triathletes only spent an average of about 5 min. stretching per week, which is considered inadequate according to recent guidelines [71]. The possible benefit that adequate regular stretching may have on the development of EAMC requires further investigation.

Although there was a trend for gender (being male) to be associated with the development of EAMC in our study, this finding was not confirmed when other variables were entered into the model predicting risk factors for cramping.

The most common muscles that cramped in this study were the gastrocnemius and the hamstrings. The upper body muscles had a much lower cramping rate. As the legs would naturally become more fatigued in an endurance triathlon, this finding again reinforces the credibility of the fatigue theory on EAMC.

The data presented in this paper show that EAMC may be associated with complex factors involved with neuromuscular fatigue. Triathletes who aspired to and achieved faster overall times in this Ironman had a higher incidence of cramps. These triathletes had trained no more than their non-cramping fellow competitors. They had

also not ever performed better over a wide range of events. Thus, in order to achieve faster times they would have had to compete at a higher intensity and would have had a greater degree of neuromuscular fatigue.

We also added to the growing evidence that triathletes with EAMC do not have significantly different electrolyte changes or change in their hydration status, compared with triathletes without.

The results of our study support the fatigue hypothesis on EAMC. Considering a number of training and performance variables, the triathletes that experienced cramping in this Ironman triathlon, had most likely induced the greatest degree of neuromuscular fatigue. The results also do not show a correlation between EAMC and changes in electrolyte concentrations or changes in hydration status, following an ultra-endurance triathlon.

Chapter 4

Summary and conclusion

Endurance athletes, such as the Ironman triathletes investigated in this research study, have a high prevalence of EAMC. It is a debilitating and disruptive occurrence and discoveries concerning aetiology and prevention strategies are highly sought after. The research done thus far on EAMC has still not revealed the exact cause.

However, studies done in the last decade by researchers at the University of Cape Town's Research Unit for Exercise Science and Sports Medicine have led to the development of a theory on a primary causative mechanism. Schwellnus et al. has proposed that it is the premature neuromuscular fatigue, during prolonged or intense exercise, that prompts cramping in exercising skeletal muscles. The basis for this argument lies in results of animal studies, clinical studies on triathletes and long-distance runners, and on information garnered from the athletes themselves, regarding the exact circumstances under which cramping occurred. The "fatigue hypothesis" has recently been supported by other studies done by researchers associated with this institution and is also compatible with our findings in this research study.

In our research study on Ironman triathletes, there was a significant correlation between EAMC and faster finishing times for the race. The triathletes who experienced cramping during or immediately after the event were similarly matched in preparation and previous performances, to those who did not cramp. We postulate that they must, therefore have exerted themselves to a greater degree in order to

achieve better results than their equally matched, non-cramping fellow competitors. These cramping triathletes would thus be more prone to premature neuromuscular fatigue and hence, according to the fatigue hypothesis, more likely to suffer EAMC.

Furthermore, the traditional "metabolic abnormality", "electrolyte concentration", "extreme environment" and "dehydration" theories have received little support in the scientific literature. Most of the available information backing these theories is anecdotal. Our study also showed no association between hydration status or electrolyte changes and the occurrence of EAMC. This is in agreement with a number of recent clinical studies on other endurance triathletes and runners.

Our study also showed no correlation between EAMC and flexibility training. However, we concluded that the level of stretching practised by this cohort of triathletes was globally of an ineffective duration and intensity to be a true representation of the beneficial effects of flexibility training on cramp prevention.

The data collected in the research study presented here may give future researchers valuable direction, and may help to focus attention on specific factors associated with EAMC. Studies should attempt to determine exactly how neuromuscular fatigue affects the spinal reflexes responsible for precipitating EAMC and how this may be prevented. The influence of an effective stretching programme on the propensity to cramp in endurance or intense exercise should also be determined.

References

1. Kantorowski P. G., Hiller, W. D., Garrett, W. E., Douglas, P. S., Smith, R., and O'Toole, M. L. Cramping studies in 2600 endurance athletes. Med Sci Sports Exerc 1990; 22 (Suppl. 4): S104.

2. Eichner ER. Should I run tomorrow? In: Tunstall-Pedoe DS (Ed.). *Marathon Medicine*. London: Royal Society of Medicine Press, 2000, pp 323-325.

3. Grundling, C. Die voorkoms van spierkrampe in fietsryers. MPrax Med thesis, University of Orange Free State . 1994.

4. Jones, B. H., Rock, P. B., Smith, L. S., Teves, M. A., Casey, J. K., Eddings, K., Malkin, L. H., and Matthew, W. T. Medical complaints after a marathon run in cool weather. Physician and SportsMedicine 1985; 13: 103-110.

5. Manjra, S. I. Muscle cramps in athletes. BSc (Med) (Hon) Sports Medicine Thesis, University of Cape Town. 1991.

6. Schwellnus MP, Derman EW, Noakes TD. Aetiology of skeletal muscle 'cramps' during exercise: a novel hypothesis. J.Sports Sci. 1997;15:277-285.

7. Schwellnus, M. P. Skeletal Muscle Cramps During Exercise. The Physician and Sportsmedicine 1999; 27 (12): 109-115.

8. Schwellnus MP, Nicol J, Laubscher R, Noakes TD. Serum electrolyte concentrations and hydration status are not associated with exercise associated muscle cramping (EAMC) in distance runners. Br J Sports Med 2004; 38: 488-492.

9. Sulzer NU, Schwellnus MP, Noakes TD. Serum electrolytes in Ironman triathletes with exercise-associated muscle cramping. Med Sci Sports Exerc 2005;37:1081-1085.

10. Manjra, S. I., Schwellnus, M. P., and Noakes, T. D. Risk factors for exercise associated muscle cramping (EAMC) in marathon runners. Med Sci Sports Exerc 1996; 28 (5 Suppl), S167.

11. Tindall, R. A survey of Exercise Associated Muscle Cramps (EAMC) in rugby players. BSc Med Hons thesis, University of Cape Town . 2001.

12. Bergeron, M. F. Sodium: The forgotten Nutrient. Gatorade Sports Science Institute 2000;13 (3): -http://www.gssiweb.com/reflib/refs/247/SSE78.cfm.

13. Bergeron MF. Heat cramps: fluid and electrolyte challenges during tennis in the heat. J Sci Med Sport 2003; 6:19-27.

14. Eichner, E. R. Heat cramps:Salt is simplest, most effective antidote. Sports Med Digest 1999; 21 (8): 88.

15. Eichner, E. R. Muscle cramps: The right ways for the dog days. Gatorade Sports Science Institute 2002., - http://www.gssiweb.com/reflib/refs/588/musclecramps.cfm.

16. Maughan, R. J. Thermoregulation in marathon competition at low ambient temperature. Int J Sports Med 1985; 6: 15-19.

17. Nicol, J. Exercise-associated muscle cramps in distance runners: The role of serum electrolytes both during and following an ultra-marathon and IEMG activity in the recovery phase post-cramp. MPhil (Sports Med) thesis, University of Cape Town. 1996.

18. Sulzer, N. U. Exercise Associated Muscle Cramping: Investigating a novel hypothesis. 2003. University of Cape Town.

19. Hiller WD, O'Toole ML, Fortess EE, Laird RH, Imbert PC, Sisk TD. Medical and physiological considerations in triathlons. Am.J.Sports Med. 1987;15:164-167.

20. Holmich, P., Darre, E., Jahnsen, F., and Hartvig-Jensen, T. The elite marathon runner: problems during and after competition. Brit J Sports Med 1988; 22 (1), 19-21.

21. Laird RH. Medical care at ultraendurance triathlons. Med.Sci.Sports Exerc. 1989;21:S222-S225.

22. Robertson, J. W. Medical problems in mass participation runs: Recommendations. Sports Med 1988; 6: 261-270.

23. Parisi L, Pierelli F, Amabile G, Valente G, Calandriello E, Fattapposta F et al. Muscular cramps: Proposals for a new classification. Acta Neurol.Scand 2003;107:176-186.

24. Jung AP, Bishop PA, Al Nawwas A, Dale RB. Influence of hydration and electrolyte supplementation on incidence and time to onset of exercise-associated muscle cramps. J Athl.Train. 2005;40:71-75.

25. Greenhalgh, T. How to read a paper. The basics of evidence based medicine. London: BMJ Publishing Group, 1997, p.45.

26. Talbot, H. T. Heat cramps. Medicine 1935;14: 323-376.

27. Edsall, D. L. New disorder from heat: A disorder due to exposure to intense heat. JAMA 1908;11: 1969-1971..

28. McArdle, B. Myopathy due to a defect in muscle glygogen breakdown. Clin Sci 1951; 10: 13-33..

29. Bank, W. J., DiMauro, S., Bonilla, E., Capuzzi, D. M., and Rowland, L. P. A disorder of muscle lipid metabolism and myoglobinuria: Absence of carnitine palmityl transferase. New Engl J Med 1975; 292: 443-449..

30. Layzer, R. B., Rowland, L. P., and Ranney, H. M. Muscle phosphofructokinase deficiency. Arch.Neurol. 1967; 17: 512-523..

31. Oswald, R. J. W. Saline drink in industrial fatigue. Lancet 1925;16 June, 1369-1379.

32. Brockbank, E. M. Miner's cramp. BMJ 1929; 12 January: 65-66.

33. Derrick, E. H. Heat cramps and ureamic cramps, with special reference to their treatment with sodium chloride. Med J Aust 1934;10 November: 612-616..

34. Talbott, J. H. and Michelsen, J. Heat cramps: A clinical and chemical study. J Clin Invest 1933;12: 533-549.

35. Read, M. and Wade, P. *Sports injuries: A unique guide to self diagnosis and rehabilitation.* Cape Town: Vlaeberg Publishers, 1994..

36. Tortora, G. J. and Grabowski, S. R. *Principles of anatomy and physiology.* 7th ed..New York, HarperCollins College Publishers, 1993.

37. McArdle, W. D., Katch, F. I., and Katch, V. L. *Exercise physiology: Energy, nutrition, and human performance.* 3rd Ed. Philadelphia: Lea and Febiger, 1991.

38. Horswill, C. A. Muscle Cramps: Causes and Cures. Gatorade Sports Science Institute , -http://www.gssiweb.com/reflib/refs/212/musclecramps.cfm. 2000.

39. McCance, R. A. Experimental sodium deficiency in man. Proc Royal Soc Lond Biol 1936; 119: 1936 245-268..

40. McCance, R. A. Sodium deficiencies in clinical medicine. Lancet 1, 823-830. 1936.

41. Speedy DB, Noakes TD, Rogers IR, Thompson JM, Campbell RG, Kuttner JA et al. Hyponatremia in ultradistance triathletes. Med.Sci.Sports Exerc. 1999;31:809-815.

42. Maughan, R. J. Exercise-induced muscle cramp: a prospective biochemical study in marathon runners. J Sports Sci 1986; 4: 31-34.

43. Layzer, R. B. and Rowland, L. P. Cramps. Physiol Med 1971; 285: 31-40.

44. Hutton, R. S. and Nelson, L. D. Stretch sensitivity of golgi tendon organs in fatigued gastrocnemius muscle. Med.Sci.Sports Exerc. 1986; 18: 69-74.

45. Nelson, L. D. and Hutton, R. S. Dynamic and static stretch response in muscle spindle receptors in fatigued muscle. Med.Sci.Sports Exerc. 1985; 17: 445-450.

46. Norris, F. H., Gasteiger, E. L., and Chatfield, P. O. An electromypgraphic study of induced and spontaneous muscle cramps. EEG Clin Neurophysiol 1957; 9: 139-147.

47. Ross, B. H. and Thomas, C. K. Human motor unit activity during induced muscle cramp. Brain 1995;118: 983-993.

48. Bertolasi L, De Grandis D, Bongiovanni LG, Zanette GP, Gasperini M. The influence of muscular lengthening on cramps. Ann.Neurol. 1993;33:176-180.

49. Eaton JM. Is this really a muscle cramp? Postgrad.Med. 1989;86:227-232.

50. Helin P. Physiotherapy and electromyography in muscle cramp. Br.J.Sports Med. 1985;19:230-231.

51. Sontag, S. J. and Wanner, J. N. The cause of leg cramps and knee pains: an hypothesis and effective treatment. Med Hypotheses 1988; 25 (1): 35-41.

52. Joekes, A. M. Cramp: A review. J Royal Soc Med 1982; 75: 546-549.

53. Dallam GM, Jonas S, Miller TK. Medical considerations in triathlon competition: recommendations for triathlon organisers, competitors and coaches. Sports Med 2005;35:143-161.

54. Sharwood KA, Collins M, Goedecke JH, Wilson G, Noakes TD. Weight changes, medical complications, and performance during an Ironman triathlon. Br.J Sports Med 2004;38:718-724.

55. Sharwood K, Collins M, Goedecke J, Wilson G, Noakes T. Weight changes, sodium levels, and performance in the South African Ironman Triathlon. Clin J Sport Med 2002;12:391-399.

56. Holly RG, Barnard RJ, Rosenthal M, Applegate E, Pritikin N. Triathlete characterization and response to prolonged strenuous competition. Med.Sci.Sports Exerc. 1986;18:123-127.

57. Noakes, T. D. Lore of Running. 4th Ed. Cape Town: Oxford University Press Southern Africa, 2001

58. Hiller, W. D., O'Toole, M. L., Laird, R. H., Burch, R., Travis, M., Massimino, A. F., and Medoff, R. J. Electrolyte and glucose changes in endrance and ultra-endurance exercise:results and medical implications. Med.Sci.Sports Exerc. 18 (suppl), S62-S63. 1986.

59. Speedy DB, Campbell R, Mulligan G, Robinson DJ, Walker C, Gallagher P et al. Weight changes and serum sodium concentrations after an ultradistance multisport triathlon. Clin.J.Sport Med. 1997;7:100-103.

60. Hew-Butler T, Almond C, Ayus JC, Dugas J, Meeuwisse W, Noakes T et al. Consensus statement of the 1st International Exercise-Associated Hyponatremia Consensus Development Conference, Cape Town, South Africa 2005. Clin J Sport Med 2005;15:208-213.

61. Cohen, I. and Zimmerman, A. L. Changes in serum electrolyte levels during marathon running. S.Afr.Med.J. 1978; 53: 449-453.

62. Rama, R., Ibanez, J., Riera, M., Prats, M. T., Pages, T., and Palacios, L. Hematological, electrolyte, and biochemical alterations after a 100-km run. Can J Appl Physiol 1994;19 (4): 411-420.

63. Rehrer NJ. Fluid and electrolyte balance in ultra-endurance sport. Sports Med. 2001;31:701-715.

64. Hiller, W. D., O'Toole, M., Massimino, A. F., Hiller, R. E., and Laird, R. H. Plasma electrolyte and glucose changes during the Hawaiian Ironman triathlon. Med Sci Sports Exerc 1985; 17 (Suppl): S219..

65. Noakes, T. D., Norman, R. J., Buck, R. H., Godlonton, J., Stevenson, K., and Pittaway, D. The incidence of hyponatraemia during prolonged ultra endurance exercise. Med Sci Sports Exerc 1990; 22(2): 165-170.

66. de Carvalho M,.Swash M. Cramps, muscle pain, and fasciculations: not always benign? Neurology 2004;63:721-723.

67. Ftaiti F, Grelot L, Coudreuse JM, Nicol C. Combined effect of heat stress, dehydration and exercise on neuromuscular function in humans. Eur.J.Appl.Physiol 2001;84:87-94.

68. Brouns, F., Beckers, E., Wagenmakers, A. J., and Saris, W. H. Ammonia accumulation during highly intensive long-lasting cycling. Int J Sports Med 1990; 11: S78-S84.

69. Rogers G, Goodman C, Rosen C. Water budget during ultra-endurance exercise. Med.Sci.Sports Exerc. 1997;29:1477-1481.

70. Bentley S. Exercise-induced muscle cramp. Proposed mechanisms and management. Sports Med. 1996;21:409-420.

71. Schwellnus M P. Flexibility and Joint Range of Motion. In: Frontera W R (Ed). *Rehabilitation of Sports Injuries. Scientific basis.* Oxford: Blackwell Science Ltd, 2003, pp 232-57.

Appendix 1: Website information for triathletes

Welcome to the Spec-Savers Ironman South Africa Research programme - 2006

Dear Triathlete

We have the privilege to inform you that scientific and medical research at the Port Elizabeth Spec-Savers Ironman South Africa triathlon has been planned in collaboration with the UCT/MRC Research Unit for Exercise Science and Sports Medicine based at the Sports Science Institute of South Africa, and Tswane University in Pretoria. This will provide a unique opportunity for a research programme to address important medical and physiological problems that are associated with participation in the Spec-Savers Ironman South Africa triathlon.

The research study will concentrate on the following 6 main components that will ultimately assist you to **improve your performance** and **improve the standard of your medical treatment** at future triathlons and other endurance events:

- Management of the collapsed triathlete
- Causes and treatment of Exercise Associated Muscle Cramping
- Preventing post-exercise decreases in immune function and upper respiratory tract (URT) symptoms
- Genetic basis for performance and physiological responses during an Ironman Triathlon
- Identifying causes of chronic Achilles tendon injuries in triathletes
- Identifying the relationship between training history, perception of effort (RPE) during the race and the subsequent recovery after the race.

How can I volunteer to participate in the research study?

As a participant in the Port Elizabeth Spec-Savers Ironman South Africa triathlon, you will be given the unique opportunity to participate in this research effort. Please understand that your participation is entirely voluntary. Please read through the details of the following six components of the study. You will be given the opportunity to participate in any number, or all the components of the study. The details of each component are summarized below and a detailed explanation of each component can be downloaded as a PDF file. If you wish to participate in the study, please **download** the information related to each component of the study (PDF file), and read through it carefully. Please bring the INFORMED CONSENT FORM of the study with you to Port Elizabeth, and then visit our RESEARCH area at the registration venue. Here we will discuss any questions you may have, and then sign the INFORMED CONSENT FORM with you. In addition please download and complete the QUESTIONNAIRES. We will let you know once the questionnaires are available. Printed copies of all the documentation will also be available at the REGISTRATION research area.

Will my participation in the research affect my preparation, race participation, or recovery after the race?

All the components of this study have been carefully designed NOT to 1) interfere with your preparation or participation in the Ironman, 2) affect your performance on race day, and 3) your recovery after the event. All the tests are not painful and non-invasive (apart from a small blood sample taken at registration and after the race).

Will I have access to the results of the study?

Once the study results are known, you will be able to access a summary of the findings of the study on the website and you can also request, this be sent to you by email. You will also be given the opportunity to attend a feedback meeting where the results of the study will be discussed. The results will only be that of the whole group, and no individual results will be made public.

Who can I contact for more information?

In the next few weeks, please feel free to contact members of the research team should you have any questions related to the study (or any component of the study). Contact details of the research team are as follows: ironman@sports.uct.ac.za or (021) 650 4572.

The following documents can be downloaded:-

1. Subject information sheets (PDF File)
2. Consent form (PDF File)
3. Questionnaires (MS Word document)
4. Summary of the study (This web page) (PDF File)
5. Adobe Acrobat Reader

Summary of each component of the research study:-

1. Management of the collapsed triathlete

The precise causes and best treatment of collapsed endurance athletes is still widely debated. We would like to see if collapsed athletes have a greater incidence of serum sodium and plasma volume abnormalities than athletes who do not collapse at the end of the race. Accordingly, if these abnormalities do exist in collapsed athletes, are intravenous fluids superior to oral fluids in the treatment and restoration of sodium and plasma volume levels? Close monitoring of sodium levels, heart rate and blood pressure and time to discharge will help our team answer these questions.

2. Exercise associated muscle cramping

The precise causes of Exercise Associated Muscle Cramping (EAMC) are still widely debated. Contrary to popular belief, heat, dehydration and electrolyte (salt) abnormalities may NOT be the cause of EAMC. In this component of the study we would like to measure these changes in triathletes who cramp, and then follow what happens once we treat these athletes. We also want to measure the muscle "twitchiness" during the recovery period, once again trying to see oif these related to changes in serum electrolyte concentrations (salt). Triathletes who are prone to EAMC may well be interested in this component of the study.

3. Post-exercise upper respiratory tract (URT) symptoms

It is well documented that intense training, as well as participation in a prolonged strenuous endurance events (such as the Ironman) can cause changes in the immune system, and may increase the risk of infections (mainly of the upper respiratory tract). In this component of the study we want to examine the immune changes, as well as find out what causes the upper respiratory tract symptoms in endurance athletes after participation in the Ironman. Triathletes that are prone to developing symptoms such as

sore throat, runny or blocked nose or cough after a race may well be specifically interested in participating in this component of the study.

4. **Genetic basis for performance and physiological responses during an Ironman Triathlon**

Athletic ability is partly determined by an intervals genetic make-up. Various genes (DNA material) have been shown to be associated with endurance performance, including the South African Ironman Triathlons. In addition it has also been suggested that the inter-individual physiological responses, such as blood salt and water imbalance, as well as the development of tendon overuse injuries, during endurance activities is partially determined by ones genes. The aim of this component of the study is to identify genes associated with performance and susceptibility to salt and water imbalances and indicators of underlying tendon pathology during the Ironman Triathlon. Volunteers for this component of the study will be asked to complete a questionnaire. At registration they will be asked to donate a small blood sample from which your genetic material (DNA) will be extracted and your blood salt levels measured. You will also be weighed before the swim and again immediately after the race. A second blood sample will also be taken after the measure to measure your blood salt levels. Some volunteers will also have there Achilles tendons scanned at registration.

5. **Chronic Achilles tendon injuries in triathletes**

Chronic Achilles tendon injuries are common in athletes participating in weight-bearing sports. It is well established that repetitive forces that are applied to the Achilles tendon (such as during running) may cause microscopic damage to the tendon. In the initial phases this may not cause any symptoms (pain or swelling). However, these changes can be observed using a technique known as soft tissue diagnostic ultrasound (non painful scan of the tendon). In this component of the study we wish to assess the changes in the Achilles tendon before and then after (immediately and 6 weeks later) the Ironman. In particular we wish to find out what damage (if any) takes place in the tendon as a result of the race, and how does this recover after 6 weeks. The findings of this study will also be linked to the genetic basis component (described in 4 above). Here we will be able to determine if your genetic make up determines how your tendons respond to a race such as the Ironman.

6. **The relationship between training history, perception of effort during the race and the subsequent recovery after the race**

The relationship between training history, perception of effort during the race and the subsequent recovery after the race is poorly understood. Knowing more about this relationship is important as it will have practical implications for the preparation for the race and minimise any health risks associated with too much physical stress which may occur after the race. Volunteers for this study will be asked to complete a short questionnaire on their training habits in preparation for the Ironman. During the race subjects will be asked to shout out a "perception of effort" score at they go past one of the 8 stations along the route. A researcher at the station will record the race number and the score. Volunteers will be sent emails on a daily basis for a week after the race with a short questionnaire on their recovery. Thereafter, they will be sent an email on a weekly basis for 12 weeks. Volunteers living near a big centre will be asked to donate a small blood sample at 1, 3, 5, 7 and 9 days after the race for the measurement of creatine kinase, a marker of muscle damage (however, blood donations are not essential for entry into the study)

If I decide to participate in the research study, what will be required of me?

The following table summarises the details of your participation in the study:-

	Details of Your Participation in the Study
Before Race	1. Download information sheets, questionnaires and consent forms from web page 2. Complete questionnaires using Microsoft Word 3. E-mail completed questionnaires to researchers at ironman@sports.uct.ac.za
At Registration	1. Hand in and sign the informed consent forms 2. Donate a sample of blood Ultrasound scan of both Achilles tendons in some athletes (Achilles Tendon component - No 5) Donate a saliva sample and have a throat swab (URT component - No 3)
Before Swim (Race Day)	1. Have yourself weighed near the start of the swim before donning your wetsuit in your costume
During Race	1. Shout out a "perception of effort" score as you go past one of the 8 stations along the route (RPE component - No 6)
Immediately After Race (Medical Tent)	1. Have yourself weighed in your running gear, without shoes, at the medical tent 2. Donate a sample of blood Ultrasound scan of both Achilles tendons in those athletes who had a scan during registration (Achilles Tendon component - No 5) Donate saliva samples and have throat swabs (URT component - No 3) Treatment of athletes with cramps and testing of unaffected volunteers (cramps component- No 2) Treatment of the collapsed athletes (collapsed athlete component - No 1)

Continuing Follow-up	**At 6 Weeks:** Ultrasound scan of both Achilles tendons (Achilles Tendon component - No 5) **Daily for 2 Weeks:** Complete symptoms questionnaire, available for telephonic surveillance calls every second day, **and only if required,** visit a designated centre for a clinical examination, donation of saliva and blood samples and have a throat swab taken (URT component - No 3) **For 12 weeks after the race:** Complete a short electronic questionnaire on your recovery daily for a week after the race; thereafter, on a weekly basis for 12 weeks. Volunteers living near a big centre will be asked to donate a blood sample at 1, 3, 5, 7 and 9 days after the race (however, blood donations are not essential for entry into this component of the study) (RPE component - No 6)

We look forward to meeting you at the Spec-Savers Ironman South Africa Registration area, and wish you well in your race preparation and participation.

Prof Martin Schwellnus, Dr Malcolm Collins, Prof Tim Noakes, and the rest of the Ironman Research Team

Appendix 2

SUBJECT INFORMATION SHEET

Dear Triathlete

We have the privilege to inform you that scientific research at the Port Elizabeth IRONMAN triathlon has been planned in collaboration with the UCT/MRC Research Unit for Exercise Science and Sports Medicine based at the Sports Science Institute of South Africa. This will provide a unique opportunity for a research programme to address important medical and physiological problems associated with the IRONMAN Ttriathlon. Each participant will be able to access a summary of the findings of the study by email, and the website, once it has been completed. You will also be given the opportunity to attend a feedback meeting where the results of the study will be discussed. The results will only be that of the whole group, and no individual results will be made public.

The research study will concentrate on the following 6 main components that will ultimately improve your performance and improve the standard of your medical treatment at future triathlons and other endurance events:

- Management of the collapsed triathlete
- Exercise-associated muscle cramping
- Post-exercise upper respiratory tract symptoms
- Genetic basis for performance and physiological responses during an Ironman Triathlon
- Chronic Achilles tendon injuries in triathletes
- The relationship between training history, perception of effort during the race and the subsequent recovery after the race.

As a participant in the Port Elizabeth IRONMAN Triathlon, you will be given the choice to participate in this research effort. Your participation is entirely voluntary. Please read through the details of the following six components of the study. You will be given the opportunity to participate in one or more components of the study. The details of each component are explained in this document, and if you wish to participate in one or more components of the study, please read through and sign the INFORMED CONSENT FORMS that relate to each component of the study. Please feel free to contact members of the research team should you have any questions related to the study (or any component of the study). Contact details of the research team are as follows: ironman@sports.uct.ac.za or (021) 650 4572.

SUBJECT INFORMATION SHEET:

COMPONENTS OF THE RESEARCH STUDY TO BE CONDUCTED AT THE 2006 IRONMAN TRIATHLON IN PART ELIZABETH

The research study at the 2006 Ironman Triathlon, comprise of six components. The detailed information on each of these components of the study is as follows:

Component 1: A study on the management of the collapsed triathlete

General information:

The aim of this study is to evaluate the optimum treatment strategies for which to treat collapsed triathletes, after an Ironman race. Although intravenous (IV) fluid replacement is a common practice in the treatment of collapsed triathletes, medical personnel need to be advised of a treatment method that will prevent possible fluid overload (hyponatraemia) which can be a very severe condition. Your participation in this trial will aid in the understanding and management of how best to correct any fluid imbalance following this race.

If you collapse during or after the Ironman Triathlon and are brought into the medical tent, you will be evaluated and treated according to the current best standard of care principles. Your legs will be elevated and your heart rate, blood pressure, mental status and serum sodium concentration will be measured. If you are confused and your sodium level is normal, other laboratory tests will be performed such as an evaluation of your body temperature and blood sugar levels. If your body temperature is normal and do not have evidence for another treatable medical condition, an IV line will be placed in your arm and the appropriate fluid will be administered - IV or oral fluid (ad libitum – you choose how much you wish to drink) - until you recover and can leave the medical tent without assistance. Your discharge will be at the discretion of the supervising medical officer. If your condition deteriorates at any time, you will be immediately removed from the trial, treated appropriately and transported to the nearest hospital.

The risk of adverse affects of placement of an intravenous line include: infection, delayed healing, bruising, physical pain, mental discomfort and possible injury to a nerve or vessel. The risk of these adverse effects are rare and every attempt to minimize these risks will be undertaken by the use of sterile technique and use of disposable, single use, material. Your blood will be used for evaluation of serum sodium or blood glucose concentration only. No

other tests will be performed on your blood and your blood samples will be appropriately discarded after these tests are performed.

We will obey the strict practices of confidentiality and anonymity. Each subject's identity will be known only to the researchers and numbers will be assigned to each sample in lieu of names. No results will be made publicly available and the scientific publication of results will never disclose subject identity.

Potential risks of this component of the study

- 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 research team without the consent of the individual subjects.
- The potential risks to subjects of blood collection are minimal and are related to 1) blood sample collection technique, and 2) the volume of blood collected prior to racing and the potential risk of a decreased performance in the race. The potential risks associated with blood collection technique from the ante-cubital veins are: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 15ml prior to the race.
- Body weight will be measured using a standard electronic scale, and there is no risk associated with this procedure.
- The risks associated with participation in this component of the study do not exceed the risks associated with competing in the Ironman competition. The administration of IV fluids will involve an invasive placement of an intravenous line. The risks associated with the placement of an intravenous line include: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or vessel. These risks will be minimized by the use of trained phlebotomists, sterile technique and disposable, single use materials. If at any time the condition of a collapsed triathlete deteriorates, the most appropriate treatment will be initiated, the trial terminated and the patient will be transported to the local hospital if necessary. The support form the local hospital is part of the normal standard medical care associated with this event.

Potential benefits of this component of the study

- The data collected in this component of the study will aid in the development of optimal treatment strategies for collapsed triathletes. Although intravenous fluid replacement is a common practice in the treatment of collapsed triathletes, medical personnel need to be advised of a more judicious approach to treatment as to avoid the deleterious effects of

fluid overload (hyponatraemia). This information will aid in the understanding and management of serum sodium disorders in collapsed triathletes by scientifically 1) evaluating the efficacy of intravenous versus oral rehydration and 2) assessing if the normalization of serum sodium levels are important in the recovery of collapsed triathletes.

Component 2: A study to determine the cause of Exercise-Associated Muscle Cramping (EAMC)

General information

The purpose of this component of the study is to determine the possible cause of exercise associated muscle cramping (EAMC) in endurance athletes. At registration, triathletes will be given the opportunity to volunteer to participate in this component of the study.

Details of the study are as follows:

- Prior to or at registration, a questionnaire detailing personal particulars, medical information, training information, and history of muscle cramping will be completed.
- At registration, a blood sample (5ml – 1 teaspoon) will be collected from the vein in the arm using standard procedures.
- Body weight will be determined at the time of registration, and on the morning before the race starts by stepping onto an electronic scale
- Should you develop muscle cramping during or immediately after the race, and if you agree to participate, you will be admitted to a designated area of the medical facility at the finish of the race.
- At the finish your core body temperature will be measured using a rectal thermometer. This procedure will take place in privacy, and entails placing a thermometer in the rectum (backside) for about 3 minutes. This procedure may be associated with mild discomfort but no pain. Normal precautions will be taken to ensure that the thermometer is clean and properly lubricated. Trained medical staff will perform this procedure.
- Disposable surface patches (electrodes) will be attached to your cramping muscle/s and also to your arm (back of the arm on the triceps muscle) to record the electrical activity of the muscles. This procedure is not associated with any pain or discomfort.
- During the time of your admission to the medial facility you will be treated for cramping using standard accepted medical procedures.
- You will be asked to stand and walk periodically (every 15min), unless you are still actively cramping. Once you are able to stand and walk with no cramping, you will be discharged from the medical facility.
- Should you develop any medical complications or if your condition deteriorates, you will be treated according to normal accepted medical practices, and this can include admission to hospital if required.

Potential risks of this component of the study

- 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 research team without the consent of the individual subjects.
- The potential risks to subjects of blood collection are minimal and are related to 1) blood sample collection technique, and 2) the volume of blood collected prior to racing and the potential risk of a decreased performance in the race. The potential risks associated with blood collection technique from the ante-cubital veins are: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 15ml prior to the race.
- Body weight will be measured using a standard electronic scale, and there is no risk associated with this procedure.
- All medical conditions, including EAMC, will be treated appropriately, based on the current standard of care or evidenced based paradigms. If at any time the condition of a triathlete with EAMC deteriorates, the most appropriate treatment will be initiated, the trial terminated and the patient will be transported to the local hospital if necessary. The support form the local hospital is part of the normal standard medical care associated with this event. Surface electrode placement and measurement of EMG activity is not associated with any known risk to the subject.

Potential benefits of this component of the study

- The anticipated benefits of this component of the study are that the results will further our understanding of the possible cause/s of EAMC in endurance athletes. In particular, once the aetiology of EAMC is better understood, this will improve our ability to prevent this condition, and to treat it effectively if it does occur.

Component 3. A study to determine the cause of post-exercise upper respiratory tract symptoms

General information

Upper respiratory tract (URT) symptoms such as a sore throat, runny or blocked nose, and throat irritation are particularly common in ultra distance athletes including triathletes. These symptoms occur mostly in the 2 weeks after a race. It has been shown to occur in 30-50% of all athletes after endurance events. It is important to understanding the relationship between exercise and URT symptoms as it is known that infections have potential negative effects for the athlete. Having an infection or not may mean the difference between being able to

compete safely, performing at a sub-optimum level at risk, or missing the event altogether because of illness. In recent years we have become aware that the symptoms of URT infections that endurance athletes suffer from after a race may NOT be caused by an infection. Instead this may reflect an irritation of the inner cell lining of the nose and throat due to allergy or perhaps pollution. However, we still need more evidence to prove this.

The aim of this component of our research is to determine if the symptoms experienced by athletes after an Ironman race are due to an infective cause (microbial agent such as a virus or a bacteria) or due to a non-infective inflammatory process in the upper respiratory tract.

The study will involve recruiting in excess of 120 triathletes who participate in the Port Elizabeth IRONMAN endurance race. You will be requested to report to a specific area at the registration desks in the 3 days prior to the event. At this time you will be asked to complete a questionnaire, and have a blood sample taken from your vein in the forearm. In addition nasal and throat swabs will be taken and you will be required give a specimen of your saliva (spit).

Immediately after you finished the race, you will be asked to report to a specific section of the medial tent at the finish, where a further blood sample and saliva sample will be taken.

You will then be asked to be available for a follow up in the 14 days after the race. Follow-up will take place in four cities (Cape Town, Port Elizabeth, Durban and Gauteng).You will be required to complete a short symptom chart every day, and you will be contact regularly (every 2 days) by a member of the research team to obtain this information. Should you develop any symptoms of upper respiratory tract irritation (such as blocked nose, runny nose, sore throat, cough) you will be asked to report to a research centre in the city (as mentioned above). There will be no financial compensation to attend this centre, but the medical consultation will be free of charge. During that visit you will be seen by a doctor, who will take a medical history, and conduct a medical examination of your upper respiratory tract (ears, nose throat and chest). In addition a blood and saliva samples will be taken. You will receive treatment and advice for the management of these symptoms.

Potential risks of this component of the study

- 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 research team without the consent of the individual subjects.
- The potential risks to you during blood collection are minimal and are related to 1) blood sample collection technique, and 2) the volume of blood collected prior to racing and the potential risk of a decreased performance in the race. The potential risks associated with

blood collection technique from the ante-cubital veins are: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 15ml prior to the race.

- The potential risks associated with the collection of saliva and throat swabs are minimal. Local minimal and transient discomfort in the upper respiratory tract is the only anticipated risk. The collection procedure will be conducted by trained staff.

Potential benefits of this component of the study

- The anticipated benefits to subjects participating in this component of the study are firstly that the knowledge of the cause of the symptoms of the URT after an endurance event will be known, secondly that the treatment of these symptoms will be based on sound scientific and clinical evidence and finally, that triathletes can be given accurate and safe advice on training during the recovery period

Component 4: A study to determine the genetic basis for performance and physiological responses during an Ironman Triathlon

General information

A study to determine the genetic basis for performance and physiological responses during an Ironman Triathlon will be conducted by the UCT/MRC Research Unit for Exercise Science and Sports Medicine at the University of Cape Town in Cape Town, South Africa, in conjunction with the Molecular Genetics Department B and Laboratory of Forensic Genetics of the Cyprus Institute of Neurology and Genetics in Nicosia, Cyprus.

The study involves donating ten milliliters (ml) (2 teaspoons) of venous blood and this will be done at race registration and after the race (five ml - 1 teaspoon). Five ml of the sample will be used for the extraction and analysis of genetic material (DNA), while the remainder of the sample will be used to measure serum electrolyte (salt) levels. In addition, body weight will be measured prior to the start of the race and again in the medical tent on completion of the race.

The DNA will only be used for scientific research purposes relating to the genetic basis of (1) athletic ability, (2) tendon and ligament overuse injuries and (3) dysnatraemia during ultra-endurance events. Personal particulars and sporting and medical questionnaires will have to be completed and this information will be treated with the strictest confidentiality and will only be used for scientific research purposes. All data will be analysed anonymously and DNA samples will be destroyed on completion of the study.

Part of the DNA extracted form the donated blood sample will be sent to the Cyprus Institute of Neurology and Genetics in Cyprus for analysis. DNA samples will be shipped to and analysed in Cyprus anonymously. DNA will be genotyped (analysed) for variations (polymorphisms) within genes relating to the genetic basis of athletic ability, tendon and ligament overuse injuries as well as water and salt imbalance during ultra-endurance events only.

Potential risks of this component of the study

- 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 research team without the consent of the individual subjects.
- The potential risks to you during blood collection are minimal and are related to 1) blood sample collection technique, and 2) the volume of blood collected prior to racing and the potential risk of a decreased performance in the race. The potential risks associated with blood collection technique from the ante-cubital veins are: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 15ml prior to the race.

Potential benefits of this component of the study

The anticipated benefits of this component of the research study are to identify genetic factors that may predispose to 1) improved performance or 2) increased risk of medical consequences (such as abnormal electrolyte imbalances). This information will eventually assist triathletes in predicting and improving their performance, and decrease their risk of medical complications during participation in triathlon.

Component 5. A study to determine the genetic risk/s associated with chronic Achilles tendon injuries in triathletes

General information

The purpose of this component of the research study is to determine if there are specific genetic factors (refer to the details for component 4) that are associated with the development of chronic tendon injuries. In addition, we want to determine what is the effect of an endurance event (such as the Ironman) on the structure of the Achilles tendon.

At registration you will be required to complete a questionnaire with personal details, training details, past injury details, and details about family history. In addition, a 5ml (1 teaspoon) blood sample will be taken from a vein in your arm. Finally, a qualified radiologist will examine both you Achilles tendons using a soft tissue diagnostic ultrasound machine. This procedure entails putting a clear jelly on your skin, and then using a probe to examine the tendon by passing it over the skin. This is not associated with any discomfort.

After you complete the race, you will be asked to undergo the same procedure (blood collection and ultrasound examination) in the medical facility at the finish. If possible, you will be asked to report to a medical centre close to your home for a final ultrasound examination approximately 6 weeks after the race. The cost of this will be free, but you will not receive any financial compensation to attend this centre.

Potential risks of this component of the study

- 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 research team without the consent of the individual subjects.
- The potential risks to you during blood collection are minimal and are related to 1) blood sample collection technique, and 2) the volume of blood collected prior to racing and the potential risk of a decreased performance in the race. The potential risks associated with blood collection technique from the ante-cubital veins are: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 15ml prior to the race.
- Soft tissue diagnostic ultrasound is a well described and common clinical diagnostic procedure that is associated with no known risk. This procedure will be undertaken by a trained radiologist.

Potential benefits of this component of the study

- The anticipated benefits of this component of the study are that the results will clarify why certain triathletes may be more or less prone to chronic tendon injuries, based on their genetic make-up. In future, this work may lead to the screening and early identification of an increased risk for tendon injuries, so that preventative measures can be undertaken.

Component 6: A study to determine the relationship between training history, perception of effort during the race and the subsequent recovery after the race

General information

The purpose of this component of the study is to investigate whether the strain experienced in the recovery period after an Ironman is directly proportional to the perception of effort and racing intensity in a group of similarly trained triathletes. The answer to this question has a practical application for training and also contributes to a better understanding of the physiological responses of ultra endurance events.

The research project will involve the following:

- About 1 week before the race you will be asked to complete a questionnaire on your training habits for swimming, cycling and running in preparation for the Ironman and your personal best times for the 3 disciplines. This will take about 30 minutes.
- You will be familiarised with the subjective scores for "perception of effort rating" and "pain assessment" before the race.
- During the race researchers will be allocated to about 12 stages throughout the race. As you swim, run or cycle past these researchers they will hold up two boards with the scores for "perception of effort rating" and "pain assessment". You will be asked to shout out your respective scores as you go past them and they will record these scores against your race number.
- You will be sent an email on a daily basis for a week after the race with a short questionnaire on your subjective perception of recovery. This questionnaire will take about 2 minutes to complete. Thereafter, you will be sent an email on a weekly basis for 12 weeks with the same short questionnaire.
- Blood samples after the race will be obtained 1, 3, 5, 7 and 9 days later for the measurement of creatine kinase.

Potential risks of this component of the study

- 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 research team without the consent of the individual subjects.
- The potential risks to you during blood collection are minimal and are related to 1) blood sample collection technique, and 2) the volume of blood collected prior to racing and the potential risk of a decreased performance in the race. The potential risks associated with blood collection technique from the ante-cubital veins are: infection, delayed healing,

haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 15ml prior to the race.

- Data for this component of the study will involve contact with subjects during the race. There is a potential risk that in the process of data collection, the performance of subjects in the race will be interfered with. This risk will be minimal, as the nature of the data collection is such that subjects will only be asked to shout out two numbers as they pass members of the research team at designated points in the race. However, should triathletes feel that this affects their performance during the race, they will be free to withdraw from this component of the study. There will be no interference with other race participants during this data collection process.

Potential benefits of this component of the study

- The anticipated benefits of this component of the study are firstly that subjects will receive a full summary of their individual results, as well as the overall findings from this component of the study. Secondly, and more specifically, the individual results will include information about their training and development of fatigue during the race which will be of interest. Finally, these results may assist triathletes in modifying their training to improve their performance.

Appendix 3

INFORMED CONSENT FORM

THE PORT ELIZABETH IRONMAN TRIATHLON 2006: MEDICAL CONSEQUENCES FOLLOWING ENDURANCE SPORTS RESEARCH PROJECT

I, _____, agree voluntarily to participate in the UCT/MRC Research Unit for Exercise Science and Sports Medicine's research project with the following components titled:-

- "A study on the management of the collapsed triathlete",
- "A study to determine the cause of Exercise Associated Muscle Cramping (EAMC)",
- "A study to determine the cause of post-exercise upper respiratory tract symptoms",
- "A study to determine the genetic basis for performance and physiological responses during an Ironman Triathlon",
- "A study to determine the genetic risk/s associated with chronic Achilles tendon injuries in triathletes",
- "A study to determine the relationship between training history, perception of effort (RPE) during the race and the subsequent recovery after the race",

performed by the University of Cape Town and the Sports Science Institute of South Africa. I have read the subject information sheets and the following procedures and concepts have been explained to me in full:

1. Completion of a questionnaire: 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 research team without the consent of the individual subjects.

2. Blood sample collection at registration, immediately after the race, and if required in the 14 days after the race: The potential risks to subjects of blood collection are minimal and are related to 1) blood sample collection technique, and 2) the volume of blood collected prior to racing and the potential risk of a decreased performance in the race. The potential risks associated with blood collection technique from the ante-cubital veins are: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 25ml prior to the race.

3. Measurement of body weight before and after the race: Body weight will be measured using a standard electronic scale, and there is no risk associated with this procedure.

4. Treatment if I collapse after the race: **(only for the collapsed athlete component).** If I collapse during or after the race I might receive either IV (drip into arm vein) or oral fluids ad libitum (as much fluid as I want). I will be attended to in a separate section of the medical tent under the supervision of a qualified doctor. I will be assessed regularly (every 15 minutes) and I understand that optimum care will be provided to me according to the current standard of care. Treatment will cease when I am alert, oriented, able to walk, and when my laboratory tests are normal. I will be transported to the local hospital if my condition requires more urgent medical attention.

5. Treatment if I develop muscle cramps during or after the race: **(only for the cramps component).** If I develop muscle cramps during after the race I will receive treatment in a designated area of the medical facility. Optimum care will be provided to me according to the current standard of care. I will be required to have a rectal temperature measurement taken, blood samples will be collected, body weight will be measured, and I will have surface electrodes attached to my muscle to measure electrical activity. Treatment will cease when my cramps have stopped and I am able to stand up and walk. I will be transported to the local hospital if my condition requires more urgent medical attention.

6. Saliva sample collection at registration, immediately after the race, and if required in the 14 days after the race: **(only for the URT component).** The potential risks associated with saliva sample collection are very small. I may experience transient discomfort as the inner lining of my throat is swabbed with a soft swab. I understand that all the normal precautions will be taken during this procedure, and that it will be undertaken by trained staff.

7. Assessment and treatment of symptoms of the upper respiratory tract in the two weeks after the race: **(only for the URT component).** I understand that should I develop any symptoms of the upper respiratory tract in the 14 days after the race, I will be required to report to a research centre in my home town, to be examined by a doctor, give a blood sample and have a throat swab as well a saliva sample taken. I understand that I will then be treated for my symptoms according to standard medical practice. I understand that I will not receive any financial compensation to attend the centre.

8. Soft tissue diagnostic ultrasound examination: **(only for the Achilles tendon component).** I understand that I will be subjected to a soft tissue diagnostic ultrasound examination of my Achilles tendons during the registration period, on completion of the race, and if possible 6 weeks after the race at a medical facility close to my home. I understand that I will not receive any direct financial compensation to attend this centre for the ultrasound, but that the investigation will be free of charge. I understand that these investigations are not associated with any risk, and will be performed by a trained radiologist.

9. The genetic basis for performance and physiological responses during an Ironman Triathlon as well as to determine the genetic risk/s associated with chronic Achilles tendon injuries in triathletes: **(only for the genetics components).** These components of the study are been performed in conjunction with the Molecular Genetics Department B and Laboratory of Forensic Genetics of the Cyprus Institute of Neurology and Genetics in Nicosia, Cyprus. At race registration, I have agreed to donate ten ml (2 teaspoon) of venous blood. Half the sample will be used for the extraction and analysis of genetic material (DNA), while the remainder of the sample will be used to measure serum electrolyte (salt) levels. I also agree to donate an additional five ml (1 teaspoon) of venous blood after the race in the medical tent which will be used to measure post-race serum electrolyte (salt) levels.

The DNA will only be used for scientific research purposes relating to the genetic basis of (1) athletic ability, (2) tendon and ligament overuse injuries and (3) dysnatraemia during ultra-endurance events. I also understand that all data will be analysed anonymously and my DNA sample will be destroyed on completion of the study. I understand that some of the DNA extracted form the donated blood sample will be sent to the Cyprus Institute of Neurology and Genetics in Cyprus for analysis. I understand that the DNA samples will be shipped to and analysed in Cyprus anonymously. I understand that the DNA will be genotyped (analysed) for variations (polymorphisms) within genes relating to the genetic basis of athletic ability, tendon and ligament overuse injuries and dysnatraemia during ultra-endurance events only.

I understand that whilst there is no direct benefit to myself, if a genetic predisposition for (1) athletic ability, (2) tendon and ligament overuse injuries and (3) dysnatraemia during ultra-endurance events can be established, then future generations will be able to establish their risk for this condition. This may allow better prevention and treatment options in the future. I understand that I will receive the overall results of the study.

I have read (or, where appropriate, have had read to me) and understood the information about this study, and any questions I have asked have been answered to my satisfaction. I agree to participate in the study, realising that I have the right to request that my DNA sample be destroyed at anytime. I agree that research data provided by me or with my permission during the project may be included in a thesis, presented at conferences and published in journals on the condition that neither my name nor any other identifying information is used.

10. Providing information on my rating of effort and fatigue status during the race: **(only for the RPE component).** I understand that I will be required to study and familiarize myself with two scales of perceived effort and fatigue before the race starts. I understand that during the race, at designated stages, I will be required to report (by shouting) my perception of effort and fatigue to members of the research team.

I have read the preceding subject information sheet and understand the testing procedures outlined therein. I understand any accompanying risks and discomforts. Knowing these risks and discomforts and having had the opportunity to pose questions answered to my satisfaction, I hereby consent to participate in this study. I understand that I may withdraw from this study at any time without further question. I have been informed that the individual data derived from my participation in these protocols will remain confidential. I understand that the medical staff and the research team have professional medical insurance.

Name of the triathlete: _____
Signature of triathlete _____

Date: _____

Name of investigator: ___Prof Martin Schwellnus_____

Signature of Investigator: _____

Date: _____ _____

Appendix 4

Department of Human Biology

UCT/MRC RESEARCH UNIT FOR EXERCISE SCIENCE & SPORTS MEDICINE
Faculty of Health Sciences, University of Cape Town
Private Bag, Rondebosch 7700, South Africa
Tel: + 27 21 650 4561
Fax: + 27 21 686 7530

2006 IRONMAN – MEDICAL AND TRAINING QUESTIONNAIRES

These questionnaires have been constructed by the Medical Research team, in conjunction with the Medical Director of the Ironman 2006. The information obtained from these questionnaires is essential for the planning of medical care during events such as the Ironman 2006. We acknowledge that the questionnaires are long, but we are asking about 20 minutes of your valuable time to complete them. The completion of the questionnaires is voluntary, all the information will be kept confidential and will only be used for research and medical care planning purposes. We suggest that you consider completing this before the event, or at the time of registration.

Prof Martin Schwellnus (Chairman, Research Team)
Dr Peter Schwartz (Medical Director, Ironman 2006)

Instructions

You can either complete the questionnaires electronically using Microsoft word or print the questionnaires and complete them manually. Please answer each question by filling in the details in the allocated space or checking one or more of the option boxes.

If you complete the questionnaire electronically using Microsoft word, please e-mail the completed forms to ironman@sports.uct.ac.za and bring the signed consent form to the research table at race registration.

If you complete the questionnaire manually, please bring the completed forms together with the signed consent form to the research table at race registration.

Please complete sections A, B, C, D and E

Please complete only the relevant questions in the following section

Section A: Personal details			
2006 Ironman Race Number			
Surname			
First Name			
Postal Address		Postal/ Zip Code	
E-mail address		Phone (day time)	code number
Date of birth	yyyy-mm-dd	Cell	
Height	cm	Gender	Male ☐ Female ☐
Weight	kg	Age	
Ethnic group (Only Required and Used for Research Purposes)	Black/African ☐ White ☐ Indian ☐ Mixed Ancestry (Coloured) ☐ Asian ☐ Other ☐		
Ancestry: Tribal or national background (eg Xhosa, Dutch, Zulu, German, Italian)	Father: Unknown ☐		
	Mother: Unknown ☐		
Country of Birth			
Dominant Hand	Left ☐ Right ☐ Both ☐	Dominant Leg	Left ☐ Right ☐ Both ☐
Occupation			
What **percentage** of your **working** day is spent in the following activities?	Sitting: _____ % Standing: _____ % Walking (Lower body activity) _____ % Manual Labour (upper and body activity) _____ %		

Section B. Racing and training history

Type of triathlon	**Sprint**	**Standard (1.6, 40, 10)**	**½ Ironman**	**Ironman**
Which triathlons have you **ever** participated in?	Yes ☐ No☐	Yes ☐ No☐	Yes ☐ No☐	Yes ☐ No☐
Year of first event				
How many events have you **ever** participated in?				
How many Olympic (or above) triathlon races have you completed over the **past 2 years**?				
Personal best time **ever**	_____ hrs:min	_____ hrs:min	_____ hrs:min	_____ hrs:min
What was your time for your last triathlon race during the **past 12 months**?	_____ hrs:min	_____ hrs:min	_____ hrs:min	_____ hrs:min
Type of running event	**5 km**	**10 km**	**21.1 km**	**42.2 km**
Which races have you **ever** participated in?	Yes ☐ No☐	Yes ☐ No☐	Yes ☐ No☐	Yes ☐ No☐
Year of first event				
How many events have you **ever** participated in?				
Personal best time **ever**	_____ hrs:min	_____ hrs:min	_____ hrs:min	_____ hrs:min
What is your best time, in a running race, in the **last 15 weeks**?	_____ hrs:min	_____ hrs:min	_____ hrs:min	_____ hrs:min

Type of event	**Two Oceans Marathon**	**Comrades Marathon**
Which races have you **ever** participated in?	Yes ☐ No☐	Yes ☐ No☐
Year of first event		
How many events have you **ever** participated in?		
Personal best time	_____ hrs:min	_____ hrs:min

What is your best average cycling speed (km/h) in a race over 80 km in the **last 15 weeks**?	Average speed: _____ Distance: _____	km/h; km
What is your best swimming performance in the **last 15 weeks**?	Time: _____ Distance: _____	min m
What is your predicted time for the entire 2006 Ironman event and each of the three splits?	Entire event: _____ Swim: _____ Cycle: _____ Run: _____	min min min min

Please answer the following questions, with your answers reflecting your average in the **most recent 15 weeks i.e. beginning December 2005 to 18th March, 2006.**	
How many days a week did you train during the **last 15 weeks**?	days/week
What distances did you train in an average week during the **last 15 weeks**?	Swim: _____ km/week Cycle: _____ km/week Run: _____ km/week
How many hours a week did you train in an average week during the **last 15 weeks**?	Swim: _____ hrs/week Cycle: _____ hrs/week Run: _____ hrs/week
What **distances** did you train in the week before the race?	Swim: _____ km Cycle: _____ km Run: _____ km
How many **hours** did you train in the **week before** the race?	Swim: _____ hours Cycle: _____ hours Run: _____ hours

Flexibility training history

Do you perform flexibility training (stretching exercises)?	Yes ☐ No ☐
If YES, please complete the rest of the flexibility training history section below:- If NO, continue completing the questionnaire from the top of page 5 (Equipment use history).	
On average, how many days a week do you perform a stretching session?	days/week
On average, how times a day do you perform a stretching session?	times/day
Please tick which muscle groups do you include in your stretching session?	☐ Hamstrings ☐ Quadriceps ☐ Calf (gastrocnemius) ☐ Calf (soleus) ☐ Groin (inner thigh) ☐ Upper body limbs ☐ Other: _____
Please tick when you stretch? (before, during and/or after exercising. You can tick more than one box)	☐ Before Exercise ☐ During Exercise ☐ After Exercise
When you stretch an individual muscle group, on average, **how long do you hold the stretch** for?	seconds
When you stretch an individual muscle group, on average, **how many times do you stretch the muscle for**?	☐ Once ☐ Twice ☐ 3 times ☐ 4 times ☐ 5 times ☐ 6 or more times

Equipment use history

Please indicate which type of **bicycle** you use?	☐ Kuota ☐ Kestrel ☐ Trek ☐ Aegis ☐ Litespeed ☐ Softride ☐ Felt ☐ Quintana Roo ☐ Javelin ☐ Cervelo ☐ Argon 18 ☐ Scott ☐ Elite ☐ Specialized ☐ Guru ☐ Giant ☐ Other: _____
Please indicate which type of **handle bars** you use?	☐ Bontrager ☐ HED ☐ Zipp ☐ Profile Design ☐ Vision Tech ☐ Oval Concepts ☐ Deda ☐ Easton ☐ Syntace ☐ Pedalsoft ☐ Kestrel ☐ Other: _____
Please indicate which type of **saddle** (Brand - model) you use?	☐ Selle San Marco- Azoto TriathGel ☐ Profile Design- Tri Stryke (with a groove) ☐ Selle San Marco- Rever Profil ☐ Fizik- Arione Tri ☐ Terry ☐ Koobi ☐ Other: _____
Please indicate which brand of **helmet** you use?	☐ Trek ☐ Bell ☐ Giro ☐ MET ☐ Other: _____
Please indicate which type of **cycling shorts** you use?	☐ Thin lycra (no padding) ☐ Padded cycling shorts ☐ Triathlon shorts with some padding ☐ Swimming costume ☐ Other: _____
Do you normally wear **underwear** together with cycling shorts?	☐ Yes ☐ No
Please indicate which type of **cycling shoes** you use?	☐ Olympic ☐ Nike ☐ Diadora ☐ Shimano ☐ Carnac ☐ Sidi ☐ Other: _____
Please indicate which type of **kit** you use?	☐ Anatomic ☐ Nike ☐ Velo ☐ Howzit ☐ Adidas ☐ Orca ☐ De Soto ☐ Louis Garneau ☐ Quintana Roo ☐ Zoot ☐ Other: _____
Please indicate which **brand of running shoe** you use?	☐ Adidas ☐ Asics ☐ Brooks ☐ New Balance ☐ Nike ☐ Mizuno ☐ Puma ☐ Reebok ☐ Saucony ☐ Other: _____
Please indicate which **type of running shoe** you use?	☐ Soft neutral shoe ☐ Mild anti-pronation shoe ☐ Motion control shoe ☐ Light racing shoe ☐ Unknown or not sure ☐ Other: _____

Section C. History of medication and supplement use

	Name of medication	Years taken
What medication, if any, are you currently using? (please list)		

Do you use protective skin sunscreen during training session or when competing?	Yes ☐ No ☐	☐ Every session	☐ Most sessions
		☐ Some sessions	☐ Very occasionally

Are you currently taking dietary supplements/vitamins?	Yes ☐ No ☐

	Name of supplement	Years taken
If **yes** to the above question, please list names of dietary, sports or vitamin supplements.	☐ Multi-vitamins	_____
	☐ Anti-oxidants	_____
	☐ Immune boosters	_____
	☐ Protein powders/supplements, Protein bars. BCAAs	_____
	☐ Creatine	_____
	☐ Caffeine	_____
	☐ Fat cutters	_____
	☐ Carbohydrate drinks/powders/gels	_____
	☐ Other: _____	_____

Have you ever used oral corticosteroids (cortisone tablets)? (If **yes**, how long ago?)	Yes ☐ No ☐	☐ 3 months	☐ 6 months
		☐ 12 months	☐ 24 or more months
Have you ever been given an injection with corticosteroids? (If **yes**, how long ago?)	Yes ☐ No ☐	☐ 3 months	☐ 6 months
		☐ 12 months	☐ 24 or more months
Have you ever been given an injection of corticosteroids in or around the **Achilles** tendon? (If **yes**, how many times?)	Yes ☐ No ☐	☐ Once	☐ Twice
		☐ 3 times	☐ >3 times
Have you ever used fluoroquinoline antibiotics? (refer to the following list)	Yes ☐ No ☐	☐ 3 months	☐ 6 months
		☐ 12 months	☐ 24 or more months

List of some fluoroquinoline antibiotics:

ADCO-CIPRIN	CIPROBAY	SANDOZ CIPROFLOXACIN
AVELON	CIPROGEN	TAFLOC
BACTIDRON	CPL ALLIANCE CIPROFLOXACIN	TARIVID
CIFLOC	DYNAFLOC	TAVANIC
CIFRAN	FACTIVE	TEQUIN
CIPLA-CIPROFLOXACIN	FLOXIN	UNIQUIN
CIPLOXX	MAXAQUIN	UTIN-400
CIPRO-HEXAL	NOROXIN	ZANOCIN
	ORPIC	

Lifestyle and habits history			
Please indicate your smoking status	Current smoker ☐	Ex smoker ☐	Never smoked ☐
If you answered yes, (past or current smoker) please complete the section on the right	Number of years of smoking:	If stopped, how many years ago:	
	What is (was) the average number of cigarettes per day:		
On average, how much alcohol do you drink per week (tots, glasses) of spirits, wine or beer?	_____ glasses beer/cider per week _____ glasses wine per week _____ tots of spirits per week		

Fluid Intake	
How do you best describe your fluid intake during an Ironman triathlon race?	(a) I drink to thirst ☐ (b) I drink as much as tolerable ☐ (c) I drink according to a predetermined fluid intake schedule ☐ (d) I drink to prevent any weight loss during exercise ☐ (e) I combine (a) with (c) ☐ (f) I combine (b) with (c) ☐ (g) Other: _____ ☐
What percentage of your fluid intake will consist of these beverages?	Water: ☐ 0-25% ☐ 26-50% ☐ 51-75% ☐ 76-100% Sports drink: ☐ 0-25% ☐ 26-50% ☐ 51-75% ☐ 76-100% Coke: ☐ 0-25% ☐ 26-51% ☐ 51-75% ☐ 76-100% Other: ☐ 0-25% ☐ 26-50% ☐ 51-75% ☐ 76-100% Specify other: _____
What will be your estimated **total** fluid intake be **(if at all)** during the **swim**?	ml
What will be your estimated **total** fluid intake be during the **cycle**?	ml
What will be your estimated **total** fluid intake be during the **run**?	ml
Rank the following sources of information on their importance in formulating your drinking strategy. (1 being most influential and the lowest number being least influential)	_____ Fellow triathletes _____ Coach / trainer _____ Magazines / books _____ Website (please specify: _____) _____ Drinking guidelines from sports associations _____ Adverts _____ Self-experimentation _____ Other: _____

Section D. Family medical history

Have any of your blood (biological) relatives <u>ever</u> had the following?

Please tick yes or no. If yes, please tick the relationship of that person to you (You may tick more than one of the relationship blocks).

Description		If Yes, please indicate the relationship
Exercise associated muscle cramps	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother
Night muscle cramps	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother
Chronic Achilles tendon injury	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother
Achilles tendon rupture	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother
Any ligament injury	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother
Asthma	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother
Allergies (in general)	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother
Heart Disease	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother
Diabetes	Yes ☐ No ☐	☐ Father ☐ Mother ☐ Brother ☐ Sister ☐ Child ☐ Grandfather ☐ Grandmother

Section E. Personal general medical history

In this section, you are asked to read through 14 questions about your personal general medical history. If you answer "yes" to any of questions 1 to 12, please complete the additional questions at the end of the section (section F on page 11).

1. In the **6 weeks before this race** (from 1st February) did you suffer from any **symptoms of flu** (fever, sore throat, blocked or runny nose, cough, wheeze, muscle aches and pains)?	Yes ☐ No ☐
2. Have you **ever** in triathlon career suffered from **muscle cramping** during or immediately (within 6 hours) after exercise (in training or competition)?	Yes ☐ No ☐
3. Have you **ever** in your triathlon career suffered from **a tendon or ligament injury** (pain, swelling, stiffness) in any tendon (including Achilles tendon, knee tendons, and shoulder tendons) or ligaments (partial or complete tear)?	Yes ☐ No ☐
4. Have you **ever** in your triathlon 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 ☐
5. Have you **ever** in your triathlon career suffered **gastrointestinal** symptoms **during exercise** including heartburn, nausea, vomiting, abdominal pain, urge to defecate (pass a stool), diarrhoea, or blood in the stools?	Yes ☐ No ☐
6. Have you **ever** in your triathlon career suffered from symptoms of the **nervous system** including exercise induced headaches, nerve tingling or loss of sensation?	Yes ☐ No ☐
7. Have you **ever** in your triathlon or cycling career (in particular with **cycling**) suffered from **injury to the genital area** including genital numbness after cycling, genital pain after cycling, genital swelling or altered sexual function after cycling?	Yes ☐ No ☐
8. Have you **ever** in your triathlon career suffered from **symptoms of allergies** including nose allergies (hay fever), allergic sinusitis, allergic asthma, skin allergies, a past history of allergies to medication, plant material or animal material?	Yes ☐ No ☐
9. Do you **currently suffer from asthma** including exercise induced asthma, or symptoms of asthma such as shortness of breath, wheezing, or chronic coughing?	Yes ☐ No ☐
10. 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 ☐
11. Do you **currently** suffer from any **symptoms of injury** in the muscles, tendons, bones, ligaments or joints?	Yes ☐ No ☐
12. Do you **currently**, or did you **in the last year**, suffer from any symptoms of **exercise related skin disease**?	Sunburn: Yes ☐ No ☐ Skin cancer: Yes ☐ No ☐ Other skin damage resulting sun exposure: Yes ☐ No ☐

13. Please tick in which anatomical area you ever had **surgery** performed.	☐ Head ☐ Neck ☐ Face ☐ Front chest ☐ Back chest ☐ Shoulder ☐ Upper arm ☐ Elbow ☐ Forearm ☐ Wrist ☐ Finger ☐ Lower back ☐ Hip ☐ Thigh ☐ Knee ☐ Lower leg ☐ Achilles ☐ Ankle ☐ Foot ☐ Abdomen ☐ Other (Specify: _____)

14. **Female athletes only:**
Please complete the following questions (14a. to 14g.) related to your menstrual cycle and other gynaecological history

14a. At what age did you start your periods (menstruating)?	(years)
14b. In the last 12 months, how many menstrual cycles did you have?	
14c. Have you ever had irregular menstrual periods in the past? (excluding pregnancy)?	Yes ☐ No ☐
14d. Have you had a hysterectomy/ovarectomy?	Yes ☐ No ☐
14e. How many times have you been pregnant?	(times)
14f. What form of contraception are you currently using?	☐ None ☐ Oral contraceptive pill ☐ Injection ☐ Intra-uterine device ☐ Sterilization (tubes tied) ☐ Other: _____
14g. If yes to question 14f. above, for oral contraceptive pill, for what reason was the pill prescribed?	☐ Not applicable ☐ Dermatological ☐ Contraception ☐ Regulate period ☐ Other: _____

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

If you have answered **YES** to any of the first 11 questions of the Personal General Medical History questionnaire in section F.

If you have completed the questionnaire manually, please bring the completed forms together with the signed consent form to the research table at race registration.

If you have completed the questionnaire electronically using Microsoft word, please email the completed forms to ironman@sports.uct.ac.za and bring the signed consent form to the research table at race registration.

Section F. Additional detailed medical history

(Please complete all the sections to which you answered "Yes" in the Personal general medical history)

1. Flu symptoms in the last 6 weeks

If you answered **YES** to **question 1** in section E, please complete the following two questions related to flu symptoms in the last 6 weeks.

(1a) Please tick which of these flu symptoms you suffered from **in the last 6 weeks**.	☐ Fever ☐ Cough ☐ Joint pains ☐ Blocked nose ☐ Wheezing ☐ Runny nose ☐ Muscle aches ☐ Any other flu symptoms (Specify: _____)
(1b) Please tick which of these flu symptoms you suffered from **in the last 7 days**.	☐ Fever ☐ Cough ☐ Joint pains ☐ Blocked nose ☐ Wheezing ☐ Runny nose ☐ Muscle aches ☐ Any other flu symptoms (Specify: _____)

2. Muscle cramping

If you answered **YES** to **question 2** in section E, please complete the following questions (2a. to 2m.) related to your cramping.

(2a) For how many years have you suffered from cramping?	(years)
(2b) Did you suffer from cramping during or after exercise in the **last 12 months**?	Yes ☐ No ☐
(2c) With what **type of exercise** is your cramping associated (You can tick more than one form of exercise)?	☐ Swimming ☐ Cycling ☐ Running
(2d) In the **last 10 races or training sessions**, how many times have you experienced cramping?	Races: _____/10 Training sessions: _____/10
(2e) What treatment/s have you had that **successfully relieved** an acute cramp? (can tick more than one)	☐ Stretching ☐ Resting ☐ Drinking fluid ☐ Ice application ☐ Massage ☐ Magnesium ☐ Salt (tablets or solution) ☐ Other (Specify: _____)
(2f) At **what point in the race or training run** do you usually first experience cramping?	☐ First quarter ☐ Second quarter ☐ Third quarter ☐ Fourth quarter ☐ After the race ☐ No pattern
(2g) In which **muscles** do you usually cramp (please list the muscle by the one which cramps most frequently (as 1) and the others after that (2-4)?	☐ Calves ☐ Hamstrings ☐ Quadriceps (thigh) ☐ Foot muscles ☐ Other (Specify: _____)
(2h) Have you **ever** suffered from cramping in your **whole body** (arms and legs)?	Yes ☐ No ☐
(2i) Have you **ever** been **admitted to hospital** following cramping?	Yes ☐ No ☐

(2j) Have you **ever** been **confused or in a coma** during or after a cramping episode?	Yes ☐ No ☐
(2k) Have you ever had **"dark urine"** in the 3 days following a cramping episode?	Yes ☐ No ☐
(2l) If you cramp, **how long** does the cramp usually last for (min)?	(minutes)
(2m) If you cramp, how **severe** is the cramp usually? (please tick).	☐ 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

3. Past Tendon and Ligament Injury History

If you answered **YES** to **question 3** in section E, please complete the following questions (3a. to 3d.) related to your past history of tendon/ligament injury/ies.

(3a) Please tick which **tendon/s** you have injured? (next column on the tright) Also indicate (tick) if your injured tendon was longsatnding pain (tendinopathy) or an acute tear/rupture	**Tendon**		**Longstanding Pain (Tendionapthy)**	**Acute Tear/ Rupture**
	Foot and ankle:	☐ Achilles tendon	☐	☐
		☐ Tibialis posterior	☐	☐
		☐ Plantar fascia	☐	☐
	Knee:	☐ Patellar tendon	☐	☐
	Elbow and wrist:	☐ Wrist extensor tendon	☐	☐
	Shoulder:	☐ Rotator cuff	☐	☐
	Other: _____		☐	☐

(3b) Please tick which **ligament/s** you have injured? (next column on the tright) Also indicate if your sprained or completely tore the ligamant.	**Ligament**	**Sprain**	**Complete Tear**
	☐ Shoulder ligaments	☐	☐
	☐ Elbow ligaments	☐	☐
	☐ Wrist ligaments	☐	☐
	☐ Finger ligaments	☐	☐
	☐ Knee (ACL)	☐	☐
	☐ Knee (MCL)	☐	☐
	☐ Knee (PCL)	☐	☐
	☐ Knee (LCL)	☐	☐
	☐ Ankle lateral ligaments	☐	☐
	☐ Ankle medial ligaments	☐	☐
	☐ Spinal ligaments	☐	☐
	☐ Other: _____	☐	☐

(3c) Please tick if you have you ever suffered from any of the following **joint capsule** injuries?	☐ Acute shoulder dislocation ☐ Chronic shoulder instability ☐ Other: _____
(3d) Do you suffer from any other **connective tissue or rheumatological diseases** or disorders? (If yes, please specify which one)	Yes ☐ No ☐ (refer to the list on the next page) (If yes, specify: _____)

List of some Connective Tissue and/or Rheumatic Diseases and Disorders		
Ankylosing Spondylitis	Lipid Storage Diseases	Pseudogout
Aspartylglycosaminuria (AGU)	Marfan Syndrome	Reactive Arthritis
Behcet's Syndrome	Menkes Kinky Hair Syndrome	Reiter's Syndrome
Crohn's Disease	Mucopolysaccharidoses	Relapsing Polychrondritis
Discoid Lupus Erythematosus	Myopathies and Dystrophies	Scleroderma
Ehlers-Danlos syndrome (EDS)	Ochronosis (Homocystinuria)	Sjogren's Syndrome
Eosinophilic Fascitis	Osteogenesis imperfecta (OI)	Systemic Lupus Erythematosus (SLE)
Giant Cell (Temporal) Arthritis	Polyarteritis Nodosa	Systemic Sclerosis
Gout	Polymyalgia Rheumatica	Wegener's Granulomatosis
Hypersentive Vasulatis	Polymyositis & Dermatomyositis	

4. Use of medicines to treat an injury before or during participation

If you answered **YES** to **question 4** in section E, please complete the following two questions related to medicine use for injuries before or during races.

(4a) 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 (Specify: _____)
(4b) 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 (Specify: _____)

5. Gastrointestinal symptoms during exercise

If you answered **YES** to **question 5** in section E, please indicate which gastrointestinal symptoms you have ever suffered from **during exercise** and, how frequently (in the last 12 months and in the last 10 races), and in which type of exercise.

Symptom	Number of times in the last 12 months **(during exercise)**	Number of times in last 10 races **(during races)**	Tick type of exercise
Nausea			☐ Swimming, ☐ Cycling, ☐ Running
Vomiting			☐ Swimming, ☐ Cycling, ☐ Running
Heartburn			☐ Swimming, ☐ Cycling, ☐ Running
Abdominal pain			☐ Swimming, ☐ Cycling, ☐ Running
Urge to pass a stool (defecate)			☐ Swimming, ☐ Cycling, ☐ Running
Diarrhoea			☐ Swimming, ☐ Cycling, ☐ Running
Passing blood in the stool			☐ Swimming, ☐ Cycling, ☐ Running

6. Diseases of the nervous system

If you answered **YES** to **question 6** in section E, please indicate which nervous disease symptoms you have ever suffered from **during exercise** and, how frequently (in the last 12 months and in the last 10 races), and in which type of exercise.

Symptom	Number of times in the last 12 months **(during exercise)**	Number of times in last 10 races **(during races)**	Tick type of exercise
Headaches			☐ Swimming, ☐ Cycling, ☐ Running
Nerve tingling in the hands			☐ Swimming, ☐ Cycling, ☐ Running
Loss of sensation in the hands			☐ Swimming, ☐ Cycling, ☐ Running

8. Allergy history

If you answered **YES** to **question 8** in section E, please complete the following questions (8a. to 8e.) related to your current and past history of allergies.

(8a) Please indicate how long (years) have you been suffering from allergies?					years
(8b) Please tick which <u>type of allergy</u> do you currently suffer from					
Nose (hay fever)	Yes ☐ No ☐	Sinusitis	Yes ☐ No ☐	Asthma (allergic)	Yes ☐ No ☐
Skin allergies	Yes ☐ No ☐	Eye allergies	Yes ☐ No ☐	Allergy to plant material	Yes ☐ No ☐
Allergy to foods	Yes ☐ No ☐	Allergy to animals	Yes ☐ No ☐	Other	
(8c) Please tick which <u>type of allergy</u> do you <u>currently take medication</u> for					
Nose (hay fever)	Yes ☐ No ☐	Sinusitis	Yes ☐ No ☐	Asthma (allergic)	Yes ☐ No ☐
Skin allergies	Yes ☐ No ☐	Eye allergies	Yes ☐ No ☐	Allergy to plant material	Yes ☐ No ☐
Allergy to foods	Yes ☐ No ☐	Allergy to animals	Yes ☐ No ☐	Other	
(8d) Please tick which <u>type of medication</u> do you <u>currently take</u>					
Cortisone nose spray	Yes ☐ No ☐	Cortisone nose inhaler	Yes ☐ No ☐	Anti-histamine tablets	Yes ☐ No ☐
Cortisone cream	Yes ☐ No ☐	Anti-histamine cream	Yes ☐ No ☐	Other inhaler / tablets or cream	Yes ☐ No ☐
(8e) Please tick which <u>symptoms of allergy</u> do you <u>currently suffer</u> from					
Sneezing	Yes ☐ No ☐	Itchy runny nose	Yes ☐ No ☐	Headache	Yes ☐ No ☐
Itchy palate	Yes ☐ No ☐	Streaming eyes	Yes ☐ No ☐	Fatigue	Yes ☐ No ☐
Itchy eyes	Yes ☐ No ☐	Blocked nose	Yes ☐ No ☐	Poor sleep	Yes ☐ No ☐
Post nasal drip	Yes ☐ No ☐	Coughing	Yes ☐ No ☐	Wheezing	Yes ☐ No ☐
In which months of the year do you <u>currently</u> have symptoms of allergies? (You tick more than one)	☐ Jan ☐ Feb ☐ March ☐ April ☐ May ☐ June ☐ July ☐ Aug ☐ Sept ☐ Oct ☐ Nov ☐ Dec				
(8f) Please tick which <u>type of allergy</u> did you suffer from in the past (NOT currently)					
Nose (hay fever)	Yes ☐ No ☐	Sinusitis	Yes ☐ No ☐	Asthma (allergic)	Yes ☐ No ☐
Skin allergies	Yes ☐ No ☐	Eye allergies	Yes ☐ No ☐	Allergy to plant material	Yes ☐ No ☐
Allergy to foods	Yes ☐ No ☐	Allergy to animals	Yes ☐ No ☐	Other	

7. Genital tract injury during cycling

If you answered **YES** to **question 7** in section E, please indicate which symptoms of genital tract injury have you suffered from **during or after cycling**, how frequently (in the last 10 sessions), how long symptoms last, and what factors prevent or relieve symptoms?

Symptom	Number of times in the last 10 cycling sessions	Please indicate when the symptoms occur	Please indicate if any of the following reduce or prevent the symptoms (can tick more than one)
Genital numbness		☐ Only during cycling ☐ During and up to 1 hour after cycling ☐ During and 1-24 hours after cycling ☐ During and > 24 hours after cycling	☐ Changing the saddle type ☐ Changing the saddle position ☐ Using padded cycling shorts ☐ Wearing no underwear ☐ Wearing additional underwear ☐ Other (Specify: _____)
Genital pain		☐ Only during cycling ☐ During and up to 1 hour after cycling ☐ During and 1-24 hours after cycling ☐ During and > 24 hours after cycling	☐ Changing the saddle type ☐ Changing the saddle position ☐ Using padded cycling shorts ☐ Wearing no underwear ☐ Wearing additional underwear ☐ Other (Specify: _____)
Genital bruising		☐ Only during cycling ☐ During and up to 1 hour after cycling ☐ During and 1-24 hours after cycling ☐ During and > 24 hours after cycling	☐ Changing the saddle type ☐ Changing the saddle position ☐ Using padded cycling shorts ☐ Wearing no underwear ☐ Wearing additional underwear ☐ Other (Specify: _____)
Altered sexual function following a cycling session		☐ Up to 1 hour after cycling ☐ 1-24 hours after cycling ☐ > 24 hours after cycling	☐ Changing the saddle type ☐ Changing the saddle position ☐ Using padded cycling shorts ☐ Wearing no underwear ☐ Wearing additional underwear ☐ Other (Specify: _____)

9. Asthma history

If you answered **YES** to **question 9** in section E, please complete the following questions (9a. to 9k.) related to your current history of asthma

(9a) Do you currently suffer from asthma?	Yes ☐ No ☐
(9b) How many years have you suffered from asthma?	(years)

(9c) How was your asthma diagnosed?	☐ A doctor taking a history and performing an examination ☐ Lung function test (blow test) but no exercise ☐ Lung function test (blow test) before and after exercise ☐ Metacholine challenge test ☐ Eucapnic hyperventilation test (rebreathing test) ☐ Other test (Specify: _____)
(9d) Which **type of asthma** do you currently suffer from?	☐ Asthma that occurs at any time but not during exercise ☐ Asthma that occurs at any time including during exercise ☐ Asthma that only occurs during exercise
(9e) Please indicate **how frequently do you currently experience the symptoms** of asthma (shortness of breath, wheezing, coughing or coughing after exercise)?	**Daytime symptoms (per week)** ☐ < 2 / week ☐ 2-4 / week ☐ >4 / week ☐ All the time **Night time symptoms (per month)** ☐ < 1 / month ☐ 2-3 / month ☐ ≥4 / month ☐ All the time **Exercise related symptoms (per 10 exercise sessions)** ☐ <1 per 10 sessions ☐ 2-3 per 10 sessions ☐ ≥4 per 10 sessions
(9f) Please indicate if you had symptoms of asthma that were severe enough to necessitate **hospital admission in the last 12 months**	☐ No hospital admission for asthma in the last 12 months ☐ 1-2 hospital admissions for asthma in the last 12 months ☐ 3-4 hospital admissions for asthma in the last 12 months ☐ >4 hospital admissions for asthma in the last 12 months
(9g) Which **symptoms of asthma** do you currently suffer from?	☐ Wheezing ☐ Dry cough ☐ Shortness of breath ☐ Tight chest ☐ Chest pain ☐ Other (Specify: _____)

(9h) What **medication do you currently use** for your asthma? (you may tick more than one option)	☐ Cortisone inhaler (e.g. Beclate, Becloforte, Becodisks, Becotide, Budeflam, Flixotide, Inflammide, Pulmicort, Qvar, etc) ☐ Salbutamol (bronchodilator) inhaler (e.g. Ventolin, Venteze, Vomax, Airomir, Asthavent etc.) ☐ Salmeterol (bronchodilator) inhaler (Serevent) ☐ Fenoterol (bronchodilator) inhaler (Berotec) ☐ Terbutaline (bronchodilator) inhaler (Bricanyl) ☐ Formoterol (bronchodilator) inhaler (e.g. Foradil, Foratec, Oxis) ☐ Ipratropium (bronchodilator) inhaler (Atrovent) ☐ Tiotropium (bronchodilator) inhaler (Spiriva) ☐ Combined cortisone and bronchodilator inhaler (e.g. Atrovent, Berodual, Combivent, Duolin, Duovent, Seretide, Symbicord) ☐ Cortisone tablets ☐ Bronchodilator tablets ☐ Leukotriene receptor antagonist tablets (e.g. Acccolate, Singulair) ☐ Other inhaler ☐ Other medication (Specify: _____)
(9i) **When do you use your medication** for your asthma?	☐ Daily (irrespective of exercise) ☐ Only before exercise ☐ Other (Specify: _____)
(9j) **How long before an exercise session** do you use your medication for asthma?	min
(9k) Have you obtained **TUE (therapeutic use exemption forms)** for your asthma medication?	Yes ☐ No ☐

10. History of previous collapse

If you answered **YES** to **question 10** in section E, please complete the following questions (10a. to 10d.) related to your current history of asthma

(10a) Have you collapsed during training or racing?	☐ Training ☐ Racing ☐ Training and racing
(10b) How many times have you collapsed in training session or races during the last **five years**?	_____ training session _____ races
(10c) When you collapse, does it mostly occur before of after the finish line / completion of the training session?	☐ Before the finish ☐ After the finish
(10d) What is the cause of you collapse?	☐ Dehydration ☐ Heat illness ☐ Hyponatremia ☐ Low blood pressure ☐ Low blood sugar ☐ Other condition (Specify: _____)

11. History of any current injury that you suffer from

If you answered **YES** to **question 11** in section E, please complete the following questions (11a. to 11g.) related to each of your current injury/ies (Space is provided for two injuries)

Injury 1	
(11a) What was the approximate date when you first became aware of the injury?	Month Year
(11b) Please indicate which side of your body is injured (if applicable)	☐ Right ☐ Left
(11c) Please indicate which anatomical area is currently injured	☐ Head ☐ Neck ☐ Face ☐ Front chest ☐ Back chest ☐ Shoulder ☐ Upper arm ☐ Elbow ☐ Forearm ☐ Wrist ☐ Finger ☐ Lower back ☐ Hip ☐ Thigh ☐ Hamstring ☐ Quadriceps ☐ Knee ☐ Shin ☐ Achilles ☐ Ankle ☐ Foot Other (Specify: _____)
(11d) Please indicate the type of structure that was injured	☐ Muscle ☐ Tendon ☐ Bone ☐ Ligament ☐ Joint Other (Specify: _____)
(11e) Please indicate in which sport (discipline) the injury occurred	☐ Running ☐ Cycling ☐ Swimming Other (Specify: _____)
(11f) Please indicate the severity of the injury (tick one box please)	☐ I only experience symptoms after exercise - Grade 1 ☐ I experience symptoms during exercise, but it does not interfere with exercise - Grade 2 ☐ I experience symptoms during exercise that may interfere with my training/ competition - Grade 3 ☐ I am so painful that I may not be able to train or compete - Grade 4
(11g) Please indicate how your injury was treated to date (you can tick more than one)?	☐ Rest ☐ Stretches ☐ Physiotherapy ☐ Surgery ☐ Strengthening exercises ☐ Equipment change ☐ Tablets ☐ Cortisone injection ☐ Other injection ☐ Orthotics Other (Specify: _____)

Injury 2	
(11a) What was the approximate date when you first became aware of the injury?	Month Year
(11b) Please indicate which side of your body is injured (if applicable)	☐ Right ☐ Left
(11c) Please indicate which anatomical area is currently injured	☐ Head ☐ Neck ☐ Face ☐ Front chest ☐ Back chest ☐ Shoulder ☐ Upper arm ☐ Elbow ☐ Forearm ☐ Wrist ☐ Finger ☐ Lower back ☐ Hip ☐ Thigh ☐ Hamstring ☐ Quadriceps ☐ Knee ☐ Shin ☐ Achilles ☐ Ankle ☐ Foot Other (Specify: _____)
(11d) Please indicate the type of structure that was injured	☐ Muscle ☐ Tendon ☐ Bone ☐ Ligament ☐ Joint Other (Specify: _____)
(11e) Please indicate in which sport (discipline) the injury occurred	☐ Running ☐ Cycling ☐ Swimming Other (Specify: _____)
(11f) Please indicate the severity of the injury (tick one box please)	☐ I only experience symptoms after exercise - Grade 1 ☐ I experience symptoms during exercise, but it does not interfere with exercise - Grade 2 ☐ I experience symptoms during exercise that may interfere with my training/ competition - Grade 3 ☐ I am so painful that I may not be able to train or compete - Grade 4
(11g) Please indicate how your injury was treated to date (you can tick more than one)?	☐ Rest ☐ Stretches ☐ Physiotherapy ☐ Surgery ☐ Strengthening exercises ☐ Equipment change ☐ Tablets ☐ Cortisone injection ☐ Other injection ☐ Orthotics Other (Specify: _____)

Appendix 5

UNIVERSITY OF CAPE TOWN

Health Sciences Faculty
Research Ethics Committee
Room E53-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • Facsimile [021] 406 6411
e-mail: [illegible]

13 January 2006

REC REF: 425/2005

Assoc Prof MP Schwellnus
Department of Human Biology
UCT/MRC Research Unit for Exercise Science and Sports Medicine
Medical School

Dear Prof Schwellnus

THE PORT ELIZABETH IRONMAN TRIATHLON 2006: MEDICAL CONSEQUENCES FOLLOWING ENDURANCE SPORTS.

Thank you for your letter to the Research Ethics Committee dated 14 December 2005, addressing the issues raised by the committee. It is a pleasure to inform you that the Ethics Committee has formally approved the above mentioned study.

Please quote the REC. REF in all your correspondence.

Yours sincerely

PROF. T ZABOW
CHAIRPERSON

Appendix 6

Subject: Ironman 2006: Additional cramps questions

Dear Ironman triathlete

About 2 weeks ago, you responded in an email to us indicating that you did suffer from muscle cramping during the Ironman 2006 race. We would very much appreciate some more details about the cramps you experienced. We constructed a series of additional questions which will assist us in getting more details about your cramping. These questions have been designed so that you can email the answers easily back to us (a series of ticks or numbers). This should take you no longer than 1 minute. The questions and possible answers are contained in this email. Please use the reply facility and then complete the questions using tick and numbers as indicated. Your cooperation will be greatly appreciated!!!!!

PS: This is the last questionnaire we will send to you about cramping.

Additional questions: Muscle cramping during Ironman 2006

Please can you answer the following nine additional questions about cramping during the Ironman 2006 event. Please use the X (capital X) to tick the appropriate answers (see example below) except questions 7 and 8 where a number is required!

Example of question and answer:

Question: Were you adequately prepared for the race?

Yes **X**

No

Personal details:

Race number: (please insert for identification purposes):

Surname: (please type out):

Question 1: In which component of the race did you suffer from cramping? (You may tick more than one)

Swimming

Cycling

Running

Immediately after the race (within 6 hours)

Question 2: How severe was your cramping during the race? (please tick).

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

Question 3: Were your muscles tired before the onset of the cramping?

Yes

No

Question 4: Were you admitted to the medical tent or the hospital following cramping?

Yes

No

Question 5: Were you confused or in a coma during or after the cramping episode?

Yes

No

Question 6: Did you have "dark urine" in the 3 days following the cramping episode?

Yes

No

Question 7: How long did the cramp last for (min)?

_____ minutes

Question 8: In which muscles did you cramp (please list the muscle/s by the one in which the cramps were most severe (as 1) to the less severe (2-4)?

Whole body (including arms)

Calves

Hamstrings

Quadriceps (thigh)

Foot muscles

Other (Please specify - type the muscle name in):

Question 9: What treatment/s did you use to relieve the cramping? (you can tick more than one)

Stretching

Resting

Drinking fluid

Ice application

Massage

Magnesium

Salt (tablets or solution)

Other (Please specify - type the treatment used in):

THANK YOU VERY MUCH FOR YOUR COOPERATION!!!