Characteristics, training loads, injury patterns and stretching habits of Australian Ironman Triathletes

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I hereby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other University or Institution

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ABSTRACT

The Ironman triathlon is an individual sport consisting of three disciplines – swimming, cycling and running. This endurance sport has grown in popularity with over 22 races annually worldwide and 24,000 participants. Despite this participation there are insufficient data concerning injuries in the Ironman triathlon and regarding athletes’ stretching and training habits, especially in Australia. The aim of this retrospective cross-sectional study was to investigate the incidence of overuse injuries in this sport according to anatomical site, and their relationships to gender, age, training hours, stretching habits and other factors. Questionnaires were provided in the race packs of 1250 participants of the Australian Ironman Triathlon in 2006. Two hundred and ninety-six questionnaires were returned giving a low response rate of 24% (74.3% male, 25.7% female). In this sample, 86.1% reported suffering an overuse injury related to competition or training in the last year. The most common site of injury was the knee (35.1% of respondents), followed by the lower back (34.1%) and the ankle/foot (30.7%). There was no statistical relationship between incidence of injury and training load, gender or age, however triathletes with a triathlon coach had a lower injury rate. Participants reported stretching less before training (41.2%) than after training (67.2%). Among those participants who stretched, the most commonly stretched muscle groups were the hamstrings (88.9%), calves (88.5%) and quadriceps (86.1%). The lower back (61.5%), upper back (31.8%) and shoulder (53.4%) muscles were not stretched by as many participants. Lower back injuries had a significant association with cycling (n = 101, r = 0.256, p = 0.01). A strong positive trend was demonstrated between stretching after training and a reduction in total injuries (p=0.059). The health professional intervention most utilised by participants was physiotherapy. The overuse injuries in Ironman triathlons in other countries were reported to be most common in the knee, ankle/foot and lower back, which
was confirmed in this study of Australian Ironman triathletes. These areas of injury need further investigation, to develop interventions to prevent or minimise injuries in this population. There is a need to educate physiotherapists on the injury profile of these athletes, so they are better prepared to treat and design interventions to prevent these types of injuries.
CHAPTER 1

INTRODUCTION

1.1 Background and rationale for the study

There is a wide range of injuries associated with participation in sport (McGrath and Finch, 1996; Pope, Herbert, Kirwan and Graham, 2000; Stevenson, Hamer, Finch, Elliot and Kresnow, 2000). These include traumatic injuries (such as acute sprains and strains), delayed onset muscle soreness associated with unaccustomed exercise, and overuse injuries. Ironman triathletes report many injuries, particularly overuse injuries, perhaps as a result of the long hours and repetitious nature of their training. (Burns, Keenan, and Redmond, 2003). Therefore, triathletes are an ideal population in which to investigate factors that contribute to such injuries (Collins, Wagner, Peterson & Storey, 1989; Egermann, Brocai, Lill and Schmitt, 2003; Korkier, Tunstall-Pedoe and Maffulli, 1994).

The present thesis reports the findings of a cross-sectional investigation (survey) of overuse injury patterns and their relationship to triathlete characteristics and training patterns, injury prevention strategies including stretching patterns, and injury management strategies in Ironman triathletes. Stretching is widely recommended and used as a preventative strategy to reduce injury risk, but there have been few studies investigating the use of stretching prior to a bout of exercise (pre-exercise stretching) or following an exercise session (post-exercise stretching) for the prevention of overuse injury (Gleim and McHugh, 1997; van Mechelen, Hlobil and Kemper, 1992).

Most studies have focused on the prevention of traumatic injuries or delayed onset muscle
soreness. The effectiveness of pre-exercise stretching is the subject of a limited number of studies (Herbert and Gabriel, 2002; Weldon and Hill, 2003; Thacker, Gilchrist, Stroup and Kimsey, 2004) and there is only one previous report on the effectiveness of post-exercise stretching in the prevention of traumatic injuries (Pope et al, 2000).

The nature of the triathlon, with three separate disciplines, means that the findings could be of relevance to the prevention or management of injuries in swimming, cycling and running, as well as other emerging multi-disciplinary sports. To date there has only been one study that has examined Ironman triathletes in Australia (Burns et al., 2003). This study had a small sample size of 95 and was conducted by interview. An exploratory study using a questionnaire may provide us with a snapshot of injuries, training and injury management in Australian Ironman triathletes. Previous studies have not considered stretching or non-traumatic injuries. A cross-sectional survey was chosen so as to sample a large number of ironman triathletes in order to examine these issues.

The present study will also identify areas that require further research relating to stretching, strengthening and the prevention of overuse injuries. The sport of Ironman triathlon is a fairly recent phenomenon and is growing rapidly in popularity with the number of participants estimated to be 5,000 in Australia and 22,000 worldwide (World Triathlon Corporation, 2010). To better understand the injuries commonly sustained, first an understanding of the sport is required and this is provided in Section 2.1.
1.2 Aims and hypotheses

1.2.1 Aims

The primary aim of this investigation was to determine the following in Ironman triathletes:

- Age, gender, anthropometric and performance characteristics
- Training characteristics including coaching
- Overuse injury patterns
- Overuse injury prevention and/or treatment strategies, and
- Injury treatment services used.

The secondary aim was to investigate the relationships between the overuse injury patterns and the other characteristics.

1.2.2 Hypotheses

Injury patterns in Ironman triathletes vary with:

- Gender
- Being coached or in a squad
- Training loads
- Stretching habits, and
- The use of orthotics.
1.2.3 Null hypotheses

Injury patterns in Ironman triathletes do not vary with respect to gender, coaching, training loads, stretching habits, or the use of orthotics.

1.3 Outline of thesis

The thesis is comprised of six chapters. Chapter 2 reviews the literature with respect to injuries in triathletes, as well as preventative strategies such as stretching and their influence on injury. Chapter 3 describes the methodology of the study and Chapter 4 reports the results of the study. A discussion of the key findings of the thesis is presented in Chapter 5, with implications for clinical practice and suggestions for further research highlighted in Chapter 6.
CHAPTER 2
LITERATURE REVIEW

2.0 Introduction and overview

For the purposes of understanding the study design and results, the literature examining triathlon injuries is discussed, including the various types of triathlon races and how they differ to the Ironman triathlon. The research concerning the prevalence and distribution of injuries in triathlon is examined, albeit understanding that because the sport is relatively new, starting in 1982, there is limited data and analysis. The research evaluating stretching is then reviewed. The research concerning stretching is far more extensive with the major modes of stretching and their effects, including those on physiology, are examined. A literature search was conducted using the following databases: Medline, Embase, CINAHL, SPORTDiscus and PEDro. The key words used in the search included triathlon, ironman triathlon, injury, stretching and prevention.

2.1 Triathlon sport

Triathlons consist of a swimming component, followed by a cycling component and then a running component. These races are usually referred to as short course, middle course (or Olympic distance) and long course or ironman distance.
2.1.1 Short course

Short course triathlons vary in distance but often include an 800 metre swim, a 21 kilometre cycle and a 7.5 kilometre run. Short course triathlons are very popular at the amateur club level allowing novice participants a chance to participate.

2.1.2 Middle course

Middle course triathlons include a 1500 metre swim, a 40 kilometre cycle and a 10 kilometre run. The middle course triathlon is used at both Olympic, Commonwealth and World Championship races. The middle course distance is also used at state level competition and is open to amateur triathletes (Vleck & Garbutt, 1998).

2.1.3 Long course

The long course triathlons consist of races that vary in distances from 1.9 kilometre to 3.8 kilometre swim; 90.1 kilometre to 180.2 kilometre cycle and a 21.1 kilometre to 42.2 kilometre run (Dallam, Jonas and Miller, 2005). The shorter distances (1.9km swim, 90.1km cycle, 42.2km run) are referred to as half ironman triathlons and the longer distances (3.8km swim, 180.2km cycle, 42.2km run) are referred to as the Ironman triathlon. Long course, half Ironman or Ironman triathlons are unique in that professionals race with amateurs and they have a qualification process.

To be eligible to participate in ironman triathlons triathletes must complete a half ironman race within a given time. Ironman triathlons have increased in popularity since their inception
in 1978 with just 15 participants. Today in excess of 20,000 people compete in ironman races all over the world with twice that number trying to qualify to gain entry. The age of competitors range from 18 to 80 years, and no matter where the race is held the distances are always the same; a 3.8km swim, 180.2km cycle followed by a 42.195km marathon.

The swim is conducted in open water with the athletes wearing wetsuits if the water temperature is less than 25 degrees Celsius. The athletes then transition from the swim to the cycle leg by removing swim goggles and cap and putting on helmets and cycling shoes. Some athletes change clothing, this is more common in the longer triathlons (O’Toole, Hiller, Smith & Sisk, 1989).

During the cycle leg drink and food stations are on the course. During this leg the triathletes must not ride within seven metres of each other, this called drafting. If caught drafting they are given a time penalty. If they repeat the offence they are disqualified. This distance of twelve metres is to ensure that there is a safe distance between the triathletes to avoid accidents and to stop the triathletes drafting. Triathletes often ride with their arms on aerodynamic bars (Figure 2.1). These bars do not have brake levers; therefore the twelve-metre distance is necessary to allow the triathletes to steer around each other. The road is usually closed to vehicular traffic during the race to protect the triathletes. Upon finishing the cycle the triathletes rack their bike, remove their helmets and change into running shoes.
The run is 42.2km with several food and drink stations on the course every 2 kilometres to four kilometres. Triathletes are allowed to carry their own food and drinks if they wish and often do wearing waist belts with bottles and pouches attached (Figure 2.2). Upon finishing volunteers ensure the triathletes stay conscious and are assisted to chairs, massage and food tents. Medical staff are in attendance at the finish line of the race and if a triathlete is suffering from dehydration intravenous drips are often prescribed (Dallam et al 2005).
2.1.4 Triathlete anthropometrics

The physical characteristics of triathletes have been measured in several studies. Collin et al (1989) found the mean body mass index (BMI) of triathletes in an Olympic distance race was 22.60\(\text{kg.m}^{-2}\) while similar to the study of Egermann, Brocai, Lill and Schmitt (2003) in which it was found the mean BMI of Ironman triathletes was 22.50\(\text{kg.m}^{-2}\). Vleck and Garbutt (1998) surveyed the Great Britain National Elite Olympic Development Squad only. Vleck et al (1998) separated the data by gender and by level of performance. This is produced in Table 2.1

<table>
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<th>Elite</th>
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<td>1.78 (0.1)</td>
<td>1.79 (0.1)</td>
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<tr>
<td><strong>Weight (kg)</strong></td>
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<td>72.20 (7.3)</td>
<td>74.14 (8.6)</td>
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<tr>
<td><strong>BMI (kg.m^{-2})</strong></td>
<td>22.17</td>
<td>22.79</td>
<td>23.14</td>
</tr>
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</table>

Table 2.1 Anthropometric characteristics of male Great Britain National Elite Olympic Development Squad from Vleck et al (1998) Data are mean (SD)
O’Toole, Hiller, Smith and Sisk (1989) in a survey of Hawaii Ironman triathletes, did not calculate BMI but did list the means for height (males 1.81m, females 1.65m) and weight (males 73.64kg, females 57.27kg) allowing us to calculate a mean BMI (males 22.48$^{kg.m^{-2}}$, females 21.04$^{kg.m^{-2}}$). Egermann et al (2003) lists the ranges for height and weight along with the mean values, but do not report the data by gender (mean height 1.79m with minimum of 1.55m and maximum of 2.04m; mean weight 72.3kg with minimum of 46kg and maximum of 107kg). None of these studies found any significant relationship between BMI and injury.

2.2 Injuries in ironman triathlon

2.2.1 Type, incidence, prevalence

The training triathletes have to perform to compete in such an event predisposes them to overuse injuries. Wilk, Fisher and Rangelli (1995) found that in surveying 150 triathletes, 78.9% of injuries suffered in triathlon were overuse in nature and more common in training than in racing. Similarly in a review of Ironman triathletes in 1988 Massimino, Armstrong, O’Toole, Hiller and Laird (1988) found 85% of the injuries sustained were non-traumatic overuse injuries. These were predominantly muscle and tendon strains, followed by stress fractures and plantar fasciitis. The authors also asked participants whether they stretched before cycling or running, or after swimming. There was a greater incidence of foot, ankle and achilles tendon injuries among individuals who did not stretch before cycling or running or after swimming. Shaw, Howat, Trainor and Maycock (2004) surveyed 258 triathletes in Australia from all distances. This cross-sectional study demonstrated that 62% of the sampled population had experienced an injury in the last twelve months. The majority of these injuries were in the lower limb and specifically the knee.
During an Ironman triathlon the athletes run a full marathon. The incidence of injuries in marathon runners has been reported as low as 26.0% to as high as 92.4% (van Gent, Siem, van Middlekoop, van Os, Bierma-Zeinstra and Koes, 2007). The majority of these injuries were in the lower limb ranging from 19.4% to 79.3%. The incidence of injuries in Ironman triathlon in this study, are divided into attributed causes which may indicate if running is associated with lower limb injuries. A recent study indicates that running after cycling can alter the pattern of running (Bonacci, Green, Saunders, Blanch, Franettovich, Chapman and Vincenzino, 2010). The researchers found that 46% of the test subjects had significantly altered knee and ankle kinematics when running after the cycle and that this was reflected in a sub-maximal VO\textsubscript{2} test. Indeed the altered knee and ankle kinematics explained 67% of the variance in the VO\textsubscript{2} results (Bonacci et al 2010). This study only sampled 15 triathletes of moderate fitness and the cycling stimulus was only for 45 minutes prior to the run. It was also mainly concerned with Olympic distance triathletes. Perhaps a study design that utilised the Ironman triathlon distance better may find greater changes in the running kinematics.

2.2.2 Bike positioning and its effect on injury

Migliorini (2000) in his review of the Italian triathlon team found that overuse injuries were mainly apparent in the lumbo-sacral region. He hypothesised that this was due to the sustained forward flexion of the vertebral column during cycling in the ‘time trial’ position, forcing the muscles to work in a lengthened position and increasing intra-discal pressure. His conclusion was to recommend that athletes need to improve their muscular elasticity and perform regular stretching exercises to the muscles of the lower limbs and shoulders. Wisbey-Roth argues that the sustained forward flexion increases the intra-discal pressure due to a lack
of core muscle endurance (Wisbey-Roth, 2010). More research is required in this area to determine the actual cause. Fitting an athlete to a bike is referred to as bikefitting. This involves measuring leg, trunk and arm length and observing the athlete cycling the bike while the bike is attached to a fixed frame. Changes are then made to the height of the saddle, length of the stem to the handlebars and the length of the cranks. Pruitt (2006) in his review of fitting more than a thousand cyclists to their bicycles found that ‘there is a window of good fit on a bike for each rider’ (Pruitt, 2006, p.15). Pruitt also remarks on this window becoming smaller the longer the cyclist has to sustain the position and the more aerodynamic the position. Ironman triathletes can be in this position for as long as 7 hours.

The angle of the saddle has been found to influence the pelvic-spine angle and affect the incidence of lower back pain (Salai, Brosh, Blankstein, Oran and Chechik, 1999). In this study once the saddle was adjusted to decrease the amount of hyperextension at the pelvic-spine junction the subject’s lower back pain improved. Over 70% of the subjects reported major improvements in lower back pain after the saddle was adjusted (Salai, et al 1999). However the population examined were not triathletes but keen cyclists, and although the findings may well be relevant to Ironman triathletes there is no research to date examining this relationship in Ironman triathletes. Sanner and O’Halloran (2000) report that the majority of cycling overuse injuries are due to a bicycle that is not properly fitted to the cyclist. They state that the knee is the most commonly injured site followed by the hip. This article did not differentiate between elite and recreational cyclists and triathletes. The authors stress that a correctly fitted bicycle can reduce overuse injuries significantly (Sanner and O’Halloran, 2000). However their study did not differentiate between elite and recreational cyclists, let alone triathletes. Notably the influence of pedal revolutions per minute or cadence can also influence overuse injuries (Mellion, 1991). This has been reported in cyclists but has not been examined in Ironman triathletes.
In a survey of 95 triathletes in the 1986 World Ironman Championships, 91% reported having an overuse injury in the past twelve months that prevented them from training or forced them to modify their training (O’Toole, Hiller, Smith and Sisk, 1989). More striking was that 72% of these triathletes reported multiple injuries during the year.

2.2.3 Orthotics and injuries in triathletes

The prevalence of lower limb injuries in triathletes is considered to range from 45% to 75% (Collins et al, 1989; Wilk et al, 1995). The use of orthotics for the prevention or treatment of these conditions is widely accepted (Burns, Crosbie, Ouvrier & Hunt, 2006). The effectiveness of orthotics in runners has been studied with varied results, with some authors in the positive (Mundermann, Stefanyshyn & Nigg, 2001) and some noting no significant effect (Hreljac, Marshall & Hume, 2000; Khodaee, Myers, Spittler, Lee, Hill & Yeakel, 2011) on injuries. The effectiveness of orthotics in triathletes has not been studied specifically.

2.2.4 Predictors of triathlon injuries

Training habits in O’Toole et al’s (1989) study seemed not to have a relationship with incidence of injury (O’Toole et al 1989). However this may have been due in part to the small sample size of 95 and the variability in training distances. O’Toole et al found that most athletes admitted to spending little time stretching and that the athletes with tendonitis in the lower limbs reported a lack of flexibility, although this was not quantified in the study. Therefore there may be a relationship between flexibility and injury in Ironman triathletes’. Williams, Hawley, Black, Freke and Simms, (1988) compared the injuries in short course
triathletes to middle course and long course or Ironman athletes. They found that a significantly greater number of injuries were associated with the long course athletes versus the short course and middle course athletes (Williams et al 1988). Williams et al concluded that this was from a combination of increased training time and a greater exposure to injury over time. Williams et al found that a higher weekly cycling distance correlated with increased injuries, and therefore was a good predictor of injury, however weekly cycling distance did not predict injuries in triathletes from a cycling background. Williams et al therefore concluded that weekly cycling distance was only a good predictor of injury in athletes who did not come from a cycling background. Shaw et al (2004) not only found that weekly training load was significantly associated with injury but performance also influenced injury. The more elite a triathlete was the greater the chance they would sustain an overuse injury (Shaw et al 2004).

Williams et al (1998) stated that the number of years involved in triathlon was a good predictor for the number of injuries. Fifty-three percent of triathletes associated their injuries with running, 50% with cycling and 11% with swimming. The principal sites of injury in this study were the knee (22%), lower back (17%), foot/ankle (14%) and shoulder (7.2%). The triathletes attributed the knee injuries to running, the lower back injuries to cycling and the shoulder injuries to swimming. Fifty-four percent of the injured triathletes believed that their injury was due to an increase in training distance. Williams et al concluded that it was not just the training volume per se that caused the injury but the increase in training volume. This was supported by the cycling training volume observed as a predictor of injury in triathletes with a cycling background.
Vleck, Bentley and Cochrane (2008) in a review of the National British Triathlon squad found in the female subjects that the number of overuse injuries correlated with the percent of training time spent doing repetitive hill runs and the frequency of other runs. In the sub-elite males that Vleck et al surveyed, running injury negatively correlated with the long run total time and the individual session duration. The elite females in Vleck et al’s study sustained less running injuries the more time they spent doing long runs per week. Vleck et al concluded that injury incidence and the relative influence of training related risk factors may differ with gender. Vleck et al recommends further research using a prospective cohort design with checks against medical records. This view is different to other studies however this study focussed on Olympic distance triathletes and not Ironman triathletes which may explain the difference.

In more recent years athletes have had to qualify to enter ironman races. This has resulted in the triathletes being fitter overall and training harder and for longer (Chapman, 2002). In more recent research Egermann et al sent questionnaires to 1833 German speaking participants in Ironman Europe 2000. The response rate was 37%. In this study 74.8% of participants reported an injury. The only significant risk factor they found was performance time. The faster the performance time the more likely the athlete would sustain an injury. This however was looking at all injuries; when examining those with non-traumatic injuries, 76.2% of these subjects had suffered from an overuse injury. Of these overuse injuries the knee, back and Achilles tendon were the most prevalent sites for injury. Shoulder and knee complaints were significantly higher in athletes under thirty years of age. Achilles tendon problems were more frequent in the higher performance level group. Athletes with more than 20 hours of training per week suffered from more back pain than the rest of the group. No relationships were found between gender and presence of training coach or medical care. The
fact that medical care and coaching were found not to influence injury incidence in this population implicates the need for more information regarding the injuries in triathletes and their anatomical distribution as well as relationship to training habits.

In summary the increased training volume correlates with an increased likelihood of injury and is a good predictor of injury.

2.2.5 Injuries in Australian Ironman triathletes

Burns, Keenan and Redmond (2003) performed a prospective study on 131 elite triathletes in Australia. Of the triathletes surveyed 50.4% reported experiencing at least one non-traumatic injury in the previous six months and 68% of all injuries were attributed to overuse. The majority of preseason injuries (71%) occurred during running. The lower limb accounted for 78% of the overuse injuries sustained during the six month preseason. During the 10 week competition season similar statistics for injuries occurred with 78% of injuries overuse and 72% of them occurring in the lower limb. Participants who never or only rarely warmed-up or cooled-down were more likely to suffer from a preseason injury. The athletes reviewed in this study were a mix of short, medium and long course triathletes (Burns et al 2003). Previous studies (Williams et al 1988) have demonstrated that long course triathletes are more likely to suffer from overuse injuries, and the lack of a warm-up or cool-down may have a greater effect on these athletes.

2.2.6 Gender differences in triathlon injuries

Vleck et al (1998) studied British national squad triathletes with 75% of respondents experiencing an overuse injury (1998). Vleck et al found gender influenced the site of injury,
with males experiencing a significantly greater number of lower back injuries. The performance level or ability of the triathletes in Vleck et al’s 1998 study did not seem to influence incidence of injury. Vleck et al found that males were less likely to experience a reoccurrence of an injury and that there were differences in the training durations between males and females. No other study to date has investigated the gender differences in injuries in triathletes.

2.3 Stretching

Stretching is an area of fitness on which every athlete, clinician and scientist has an opinion (Gleim and McHugh, 1997). Debates about stretching result from the lack of consensual definitions and measurements (Gleim et al 1997). The term stretching can be defined as you are trying to elongate or change the length of a structure, in this case specifically the muscle-tendon unit (Pope, Herbert, Kirwan and Graham, 2000). The ability to change the flexibility or range of a joint or muscle by stretching has been shown to occur (McHugh and Kjaer, 1995). Stretching exercises are commonly the focus of physiotherapists in rehabilitation and injury prevention (Ylinen, 2008). Specific stretching programs are often prescribed to the athlete aiming to restore normal range of movement or to prevent shortening of the muscle (Verrall, Slavotinek and Barnes, 2005). Pruitt recommends that ‘flexibility is important, especially as we age, to avoid injury and to allow a comfortable but aerodynamic position on the bike’ (Pruitt, 2006. p.5). This appears to be a common held belief in the popular cycling and triathlon periodicals based perhaps more on anecdotal observation rather than statistically significant evidence (Australian Cyclist Sept 2008, p38).
2.3.1 Definitions of stretching

Stretching is grouped into two broad categories passive and active (Ylinen, 2008). Active stretching uses voluntary contractions of agonist muscles to produce a change in the range of motion. The change of range of motion will depend on the resistance of the muscle being stretched and the strength of the agonist muscle performing the movement. Examples of active stretching include dynamic and ballistic. Passive stretching uses an external force to produce a stretch. This external force can be a therapist, athlete, machine, weight or object. Examples of passive stretching include active assisted, sustained stretches and proprioceptive neuromuscular stretches.

*Active assisted stretching*- A therapist applies a passive stretch to the athlete while the athlete either assists movement by contracting the agonist muscles, or resists the movement by contracting the agonist muscles which the therapist resists (Weerapong, Pornratshanee, Hume, Patria, Kolt and Gregory, 2004).

*Dynamic stretching* – The athlete moves the muscle in a rhythmical fashion using the agonist and antagonist muscles to produce the movement. This movement can be slow or fast and can be through the entire range or through a small range. If the movement is forceful and fast, it is usually termed a ballistic stretch (Weerapong et al, 2004).

*Static stretching* – Involves moving the joint to the end of range where there is considerable resistance from muscle tension. This position is then held for some time. This time can vary from 5 to 60 seconds, and often the stretch is repeated (Weerapong et al, 2004).
The two main types of stretching used by athletes are static and ballistic (Pope, Herbert and Kirwan 1998). Static stretching is defined as a sustained hold of 15 seconds or greater while ballistic stretching is defined as short repeated pulses with each pulse lasting less than two seconds and usually repeated in excess of five times (Smith, Brunetz, Chenier, McCammon, Houmard, Franklin and Israel, 1993). The amount of time static stretches are held varies between studies. Madding (Madding et al, 1987) and Taylor (Taylor, Dalton, Seaber and Garrett, 1990) suggest that stretches held for 12 to 18 seconds increase flexibility to the same degree as holding the stretch for two minutes.

Roberts (Roberts, 1999) compared five second hold static stretching to fifteen second static stretching. They found that both groups demonstrated gains in flexibility over five weeks when compared to controls. The 15 second group gained more flexibility in active movements when compared to the 5 second group; however there was no difference between the two groups in passive movements.

Comparisons of ballistic and static stretching indicate that they are both effective in increasing range (Lucas and Koslow, 1984), but static stretches are regarded as safer due to the slow onset of resistance in performing them (Moore and Hutton, 1980; Osternig, Robertson, Troxel and Hansen, 1990). Other stretching methods include passive stretching, requiring the use of a partner, isometric, static stretching against an immobile force, and proprioceptive neuromuscular facilitation (PNF) stretching.
There are two predominant PNF techniques used in the sporting arena. The most commonly taught PNF in Australia is the contract-relax technique. This contract relax technique involves passive movement to the onset of muscle stretch, then a voluntary muscle contraction by the stretches muscle against resistance before being passively being moved into a greater range (Calder and Sayer, 1992). The second PNF technique taught is the reciprocal relaxation method where the agonist muscle produces the stretching force on the muscle to be lengthened. Some studies suggest that PNF techniques can result in greater gains in range than passive stretches (Sady, Wortman and Blanke, 1982; Wallin, Ekblom, Grahn and Nordenberg, 1985). These differences are apparent immediately post stretch and are less obvious over time (Hutton, 1992).

2.3.2 Different stretching techniques

Stretching is used to improve range of motion and/or change the elastic characteristics of the muscle-tendon system. Resistance to stretch is in the connective tissue surrounding the joints, passive components of the muscle-tendon system and the contractile components of the muscles (Pope et al, 1998). The passive components of resistance include the viscosity and elasticity of the muscle and tendon connective tissues, joint ligaments and capsules, subcutaneous tissues such as fascia and skin. The active components of resistance include voluntary and involuntary muscle tension influenced by local receptors and the central nervous system. Stretching techniques aim to reduce the extent of the passive and active components of resistance (Anderson 2005; Bandy and Irion 1994; Smith, Brunetz, Chenier, McCammon, Houmard, Franklin and Israel, 1993;; Taylor, Dalotn, Seaber and Garrett, 1990; Weldon and Hill, 2003).
The resistance due to the viscous and elastic components of connective tissue varies depending on their structure and amount of each. Therefore different connective tissues have different properties and each type will respond in its own way to stretching. If a connective tissue has a large content of elastic fibres it will release power quickly whereas if it is high in viscous elements it will release power more slowly. Stretching can cause elastic and plastic deformation in connective tissue. After stretching elastic fibres will return to their previous state however viscous elements will allow more longstanding changes in tissue structure (Woods, Krista, Bishop, Phillip, Jones and Eric, 2007).

Continuous or repeated stretching with enough force will cause plastic changes due to creep phenomenon in connective tissues. The resistance to stretch will then decrease. Plastic changes are reported to change primarily in the musculotendonous junction. If connective tissue is stretched beyond a normal physiological range mechanical weakening will occur although tissue damage may not be evident (Weldon et al, 2003).

Change in the elastic nature of soft tissues is called the hysteresia phenomenon. The primary factors in this change include force, duration and tissue temperature. Slow stretching is recommended for plastic change, however if the force applied is too small plastic deformation will not occur. Garrett, Nikolaou, Ribbeck, Glisson, and Seaber, (1988) found actively contracted muscles can withstand 15% more stretching force than passive relaxed muscles. The energy absorption capacity of active muscles is 100% more than relaxed muscles (Garrett et al 1988). Therefore muscles can endure greater amounts of stress while active than when passively stretched. It is suggested by Ylinen (2008) that tired muscles will be less durable under stress, but the author has no evidence to validate this statement.
2.3.3 Static stretching

Henricson, Larsson, Olsson and Westlin (1983) studied the effects of static stretching (SS) on the calf muscles of badminton players. The subjects performed five static stretches holding each stretch for fifteen seconds, three times a week for twelve weeks. The five degree gain in dorsiflexion was not statistically significant compared to controls. Grady and Saxena, (1991) studied the effect of static stretching of the calf muscles and found no significant difference after six months.

Toft, Espersen, Kalund, Sinkjaer and Hornemann, 1989) examined the passive tension in dorsiflexion of the ankle in soccer players before and ninety minutes after a single contract relax stretch of the ankle plantarflexors. Initially the stretching lowered the passive tension by 18% and when the stretch was continued twice a day for three weeks the passive tension lowered by 36%.

McNair, Dombroski, Hewson and Stanley, (2000) tested the effects of static stretching and continuous passive motion on ankle dorsiflexion. The force of resistance was measured afterwards on an isokinetic machine. The range of motion of the ankle joint was found to increase significantly by 16%. The static stretching was not found to change the stiffness of the ankle joint significantly.
Duong, Low, Moseley, Lee and Herbert (2001) studied the stiffness of the ankle joint after a long duration stretch of 20 minutes. Duong found that ankle stiffness did decrease after long duration stretches however this stiffness had recovered by 43% after two minutes.

Youdas, Krause, Egan, Therneau and Laskowski (2003) found that repeated ankle dorsiflexion stretches did not change the range of motion of the ankles in healthy subjects after six weeks. Bohannon (1984) studied the effect of hamstring stretching lasting eight minutes. Hip joint range of motion was measured fifteen seconds after stretching. After three days the mobility of the stretched group had improved by 7 degrees compared to 1.5 degrees in the control group. One day later the treatment group had dropped to 4.5 degrees and 0.5 degrees in the control group. The difference in the groups was not considered significant.

Borms, Van Roy, Santens and Haentjens (1987) compared the static stretching of the hamstring muscles using different durations of stretch times. The times compared were 10 seconds, 20 seconds and 30 seconds. Stretching was performed twice weekly for 454 minutes for ten weeks. The mean increase in all groups was 13 degrees. Hugh et al in 1992 tested the effects of static stretching of hamstring muscles for 45 seconds. The viscosity and elastic components of the muscle decreased by 15%, however this change reduced to baseline levels after 10 minutes. Bandy, Irion and Briggler, (1997) compared the static stretching of hamstring muscles using different durations of stretch times in healthy subjects with short hamstrings. Three durations were compared, 15, 30 and 60 seconds. Stretches were performed once daily, five days a week for six weeks. Hip flexion increased by 4 degrees in the 15 second group whereas the 30 and 60 second groups had an increase of 12 degrees in hip flexion. The same subjects were then separated in to two groups of 30 and 60 seconds,
with no difference in the hip flexion. Stretching once or three times a day made no statistical
difference to the range following a program of 30 or 60 second stretches.

Some researchers believe that the change in resistance or range of motion is due to a change
in stretch tolerance. This is a change in the nerves responses to a stretch stimuli, and that this
response reduces after sustained stimulation. Magnusson, Simonsen and Aagard (1996)
assessed subjects who stretched by reaching down for their toes and held it for 90 seconds.
Stretching resulted in a 30% reduction in resistance. The electric activity of the muscles
remained constant during the stretch and measurement, so the researchers concluded that the
decrease in resistance was due to mechanical changes and not caused by relaxation. The
measurements were repeated after 45 minutes and the effects were not discernable. Li,
McCure and Pratt, (1996) evaluated the effect of sustained stretch on hamstring muscles for
15 seconds repeated ten times daily for three weeks. The range of the hip flexion increased by
12 degrees, and the researchers concluded that it was important to determine the number of
times the stretch was performed as well as the duration it was held for.

Gajdosik in 1991 compared passive compliance and the length of clinically short hamstring
muscles compared to muscles that were not considered to be short. There was a difference of
13 degrees in the straight leg raise. The torque versus angle curve in the stiff legs was shifted
to the left Magnusson et al, 1996). The stretching was stopped when the subjects felt they had
reached maximum stretch or when an increase in electromyography activity was detected.
The maximal passive torques did not differ between the groups and because the passive
compliance was greater in the stiffer hamstring muscles the change of muscle length was less
in the more inflexible group. Magnusson et al (1996) stretched the hamstrings of subjects for
45 seconds ten times daily. The magnitude of the initial increase ranged from 5 to 17 degrees. Total stretching time was 9000 seconds. Magnusson did not find any change in the torque-angle curve indicating that the increase in range was due to an increased stretch tolerance rather than a viscoelastic change.

Chan, Hong and Robinson (2001) evaluated the effects of two different static stretching protocols on flexibility and passive resistance of the hamstring muscles. One group performed two series of five repetitions of 30 seconds. Stretching was performed three times a week for four weeks. The second group did one series of five repetitions for 30 seconds three times weekly for eight weeks. The mobility did not change in the control group, pain free mobility improved by 9 degrees in the four week stretching group and in the eight week group it improved by 11 degrees, however this difference was not significant. The authors stated that the improved mobility in the four week group was primarily due to an increased tolerance to stretching. The eight week group exhibited some adaptation to the connective tissues with lower resistance at the end of range. The researchers suggested that treatment duration was more important than the repetition of the stretches.

Feland, Myrer, Schulthies, Fellingham and Meason (2001) studied hamstring stretches in 65 year old subjects. Stretch duration times for the different groups were 15, 30 and 60 seconds repeated four times with 10 second intervals between. Stretching was performed four times per week for six weeks. Flexibility increased by 4, 8 and 12 degrees respectively in each group. The elderly individuals appeared to gain more benefit from longer duration stretches than younger individuals. On follow-up the increase in range returned to baseline levels over time. This research has some bearing on the Ironman triathletes as some race in this age
category and older. Taylor et al (1990) in a muscle-tendon unit laboratory rat specimen was able to show that the greatest effects of static stretching occur in the first 12 to 18 seconds of the stretch and 75% of the changes in the viscoelastic properties of the muscle-tendon unit occur in the first four stretches. This research would tend to suggest that a small number of stretches will lead to the most elongation in repetitive stretching. Total time for stretching per week would appear to be more important than time spent on individual stretches. Table 2.2 lists most studies on static stretching and their effects on range of motion.

In summary static stretching appears to have a significant effect on resistance and range of motion in healthy subjects. In studies measuring changes in resistance after stretching, there were differences but their effects were short lived.
<table>
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<tr>
<th>Researcher</th>
<th>Duration of single stretch (sec)</th>
<th>Repetitions</th>
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<th>Duration (weeks)</th>
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**Table 2.2** Test results of hamstring muscle stretches on healthy subjects. The changes in angle have been measured at the hip joint with the knee extended or of the knee with the hip flexed at 90 degrees.
2.3.4 Contract relax stretching

Contract relax stretching is used frequently by athletes and health professionals (Ylinen, 2008). A pre-stretch position is used by moving the joint as far as possible until the resistance is significant. The subject then uses isometric contraction to tense the antagonist muscles while a partner resists the movement or an object resists the movement. The subject then relaxes the muscles while the partner stretches the joint further when the muscle-tendon unit becomes tight again. Often this cycle is repeated. Nelson, Kokkonen, Eldredge, Cornwall and Glickman-Weiss, (2001) studied the influence of the time duration of contraction on the efficacy of the contract relax stretching method. Contraction times of three, six or ten seconds did not show any statistically significant differences. Nelson et al (2001) found in the same study that tiring of the muscles did not improve stretch results.

Feland et al (2004) compared the effectiveness of sub maximal and maximal contraction, in contract-relax stretching. Subjects were chosen if they could not reach 70 degrees of hip flexion during a straight leg raise. The subjects were randomly assigned to one of three treatment groups performing 20%, 60% and maximal voluntary contraction of the hamstring muscles compared to a control group. The stretching groups performed three stretches for 6 seconds with a ten second rest between contractions, once a day for five days. There were no differences between the treatment groups, but all treatment groups had a significant increase in flexibility compared to the control group. This would suggest that sub maximal contractions are just as beneficial in improving flexibility as maximal contractions in contract relax stretching of tight hamstring muscles.
2.3.5 Comparison of different stretching methods

Various stretching methods are used in the athletic setting however there is some confusion as to which is more effective. Holt, Travis and Okita, (1970) compared static stretching, ballistic stretching and contract relax stretching. All groups performed the stretches three times per week. Each group used each stretching technique for one week. The sit and reach test was used as the assessment tool. Flexibility increased by two centimetres in the static stretching and ballistic stretching groups. In the contract relax group mobility increased by five centimetres. This would suggest that contract relax stretching is more effective.

Hartley-O’Brien, (1980) compared six different stretching methods on hamstring flexibility. These were, contract relax stretching with a six second contraction, passive stretching for one minute, dynamic stretching relaxation stretching, active proprioceptive neuromuscular facilitation with six second contractions, and passive proprioceptive neuromuscular facilitation. Flexibility was shown to improve in all six methods however there was no significant difference although static stretching did give slightly greater improvements.

Bandy, Irion and Briggler (1998) compared agonist contraction stretching and static stretching on hamstring flexibility. The agonist contraction group used 5 second contractions for a total stretching time of 30 seconds. The static stretching group used 30 second static stretching, with both groups performing the stretches once a day. Treatments were performed for five days a week for six weeks. The static stretching group had a mean improvement of 11 degrees whereas the agonist contraction group had an increase of four degrees. The researchers concluded that the strength of the agonists did not provide a stimulus as strong as
the static stretching and that pre-contraction of the antagonist muscle may be needed to relax it sufficiently for the agonist to improve range of motion. Therefore this study seems to suggest that static stretching is more effective than contract relax stretching.

Feland et al (2001) compared the effects of contract relax stretching and static stretching in healthy elderly subjects. In both stretching methods the stretch lasted a total of 32 seconds. The contract-relax group had an increase of 5 degrees and the static stretching group had an increase of 4 degrees which was not significantly different. The control group in this study only had an increase of 1 degree which was significantly different from the stretch groups. Feland et al concluded that the mode of stretching in this study was not as important as was the amount of stretching time. The results of this study would suggest that there is little if any difference between static stretching and contract relax stretching.

Payne, Morin, Seibenecher and Langois (2003) compared three different stretching methods for the hamstring muscles, static stretching, agonist contract stretching and contract relax stretching. In all three groups the total amount of stretching was 30 seconds. Stretching was performed once a day, five days a week for five weeks. Significant increases in hip flexion were attained in all three groups with no significance difference between the groups. Swank, Funk, Durham, and Roberts, (2003) found that adding light weights to stretching exercises increased passive range of motion in the elderly compared to a control group performing the same stretching exercises only. While interesting the age of the subjects means the relevance of this study to triathletes is limited.
2.3.6 Electrical activity of muscles during stretching

Using surface electromyography (sEMG) researchers have investigated the relationship between stretching and the level of muscular activity. Moore and Hutton, (1980) examined the effects of three stretching techniques, static, contract-relax and contract relax with agonist contraction, on the electrical activity of the hamstring muscles and on hip mobility. Minimal activity was recorded in hamstring muscles with the static stretching method. Contraction of the antagonist muscles prior to stretching caused greater amounts of electrical activity during the initial stages of the contract relax and the contract relax with agonist contraction stretches. In the contract relax with agonist contraction method, active contraction of the agonist muscles increased the activity in the antagonist muscles due to co-contraction. The researchers did not see evidence of reciprocal inhibition in the antagonist muscles. Resistance to stretch was greatest in the contract relax with agonist contraction method. Flexibility did increase in all individuals and there was not a significant difference in mobility between the three different methods. The key issue is the paradox between the increase in range of movement and the increase in muscle activity. The contract relax stretching obtains a greater range even with the muscle not being passive. The explanation for this requires further research.

Etnyre and Abraham (1986) compared the effects of three different types of stretching on alpha motor neurone function using the H-reflex. The reflex decreased most following the contract relax agonist contraction stretch in the soleus muscle. The contract-relax method
reduced reflex function more than static stretching however this difference was absent after 1 second. This would suggest that the muscle contraction reduces the reflex contraction to stretch allowing greater range.

Osternig, Robertson, Troxel and Hansen, (1990) compared the effects of the same three stretching methods on the electrical activity of the hamstring muscles and knee mobility in sitting. EMG activity steadily decreased in the static stretching method while the activity increased in the contract relax and in the contract relax agonist contraction methods. This increased muscle activity was thought to increase muscle stiffness however the increase in flexibility was 5% less in the static stretching group. Again the paradox of Moore and Hutton’s (1980) study is brought to the fore.

McHugh, Kremenic, Fox and Gleim (1998) demonstrated that an increase in electrical activity caused by muscle contraction in a contract relax stretch disappeared during relaxation and did not cause an increase in resistance. More power was needed in the contract relax technique to obtain an increase in range of motion, than in the static stretch method, due to an increase in the stretch tolerance.

Halbertsma, Mulder, Goeken and Eisma, (1999) studied the effects of passive stretching of the hamstring muscles using a machine that performed a straight leg raise with the individual lying supine. The subjects stopped the stretch when they began to feel pain. The range of motion was still increased as long as an increase in stretch could be tolerated. The leg was let down immediately once movement stopped. Stretching was repeated at two minute intervals
four times. Mobility did not improve in repeated stretches and tissue resistance did not significantly change. The researchers concluded that short-term stretching does not improve tissue flexibility when stretch force does not exceed the tolerance of pain. The EMG measured was minor and was greatest during the middle of the movement and not at the full stretch position. There may not have been enough training sessions in this study.

In a series of studies conducted by Guissard, Duchateau and Hainut, (2001) the spinal reflex response during passive stretching of the calf muscles was studied. The activities of the soleus muscle were recorded in response to electrical stimulation for different dorsiflexion angles of the ankle. Both the Hoffman and tendon reflexes were reduced during stretching. Once the ankle joint returned to the neutral position the reflexes returned to normal. After thirty static stretching sessions the ankle dorsiflexion had increased by 31%. This improvement was attributed to a decrease in passive muscle stiffness. The changes were maintained one month after the stretching regime ceased, however the reflex activities had returned to the original level. This may suggest that the time course of the neural changes is different to the mechanical changes. The improved flexibility was noticed after ten sessions suggesting that in the Halbertsma et al study, four sessions was not sufficient to elicit a change in the mechanical stiffness of the muscle.

2.3.7 Pre and post exercise stretching

Stretching is often performed prior to exercise in the belief that it minimises injury (Pope et al 2000). The view is held that by improving the compliance of the muscle it is less likely to tear during sporting activities (Smith et al 1993). Stretching is often included as part of the
warm-up before sport however the research has yet to determine the importance or type of stretching that should be performed (Pope, Herbert, Kirwan and Graham, 1999).

Inadequate warm-up exercises have been associated with strains to muscles and tendons (Knight, Rutledge, Cox, Acosta and Hall, 2001), and muscle tightness can predispose athletes to certain injuries (Ekstrand, Gillquist, Moller, Oberg and Liljedahl, 1983). Shrier, (1999) argues that there is no evidence that stretching before exercise prevents injury. Thacker et al (2004) in a systematic review of the literature concluded that ‘There is not sufficient evidence to endorse or discontinue routine stretching before or after exercise to prevent injury among competitive or recreational athletes’. McNair et al (2000) would argue that ‘it is important for rowers to include hamstring stretches in their training programmes’. Their argument was that tight hamstrings would increase the likelihood of back pain by limiting the amount of pelvic rotation (Reid and McNair, 2000). Schur, (2001) states that these two opposing views may not be too dissimilar, and goes on to suggest that there may be a difference between stretching abnormally tight tissue into a normal range of motion as opposed to stretching normal tissue into an excessive range. Witrouw, Mahieu, Daneels and McNair (2004) suggested that stretching and its effectiveness on reducing injuries may be influenced by the demands of the sport. The researchers hypothesize that sports that are high impact such as benefit from stretching, whereas low impact sports such as swimming may show little benefit from stretching in injury prevention. Witrouw et al, suggests that when this approach is applied to the current research that the results support this hypothesis.

Safran, Garrett, Seaber, Glisson, and Ribbeck, (1988) and Williford, East, Smith and Burry, (1986) both demonstrated that warming up prior to stretching improved the muscles ability to
withstand more force prior to failure and improved range of motion. Post exercise stretching has focused on reducing post exercise pain, or delayed on set muscles soreness (DOMS) (Thacker et al 2004). Some studies suggest that post exercise stretching does reduce post exercise pain (Buroker and Schwane, 1989) however other studies suggest that this is not the case (Johansson, Lindstrom, Sundelin and Lindstrom, 1999). Bixler and Jones, (1992) found that a half time warm up and stretching routine reduced the incidence of sprains and strains in the third quarter of high school football games. The third quarter is the most injurious and the reduction in injuries in this study was significant for sprains and strains only. Bixler et al (1992) concludes by suggesting a large scale randomised control study is required to confirm these results. The importance of the warm-up in this study cannot be overlooked and limits the importance one can place on the stretching. In addition the stretching was not post exercise but rather pre exercise with reference to the injury study time frame of the third quarter.

Verrall, Slavotinek and Barnes, (2005) found that stretching hamstring muscles whilst the Australian Rules football players were fatigued reduced the incidence of hamstring tears. The stretching was performed in conjunction with sport specific training drills and an increase in high intensity anaerobic interval training. Unfortunately the researchers were unable to discern which of these strategies were most effective but they did demonstrate that for this sporting population hamstring injuries were reduced in prevalence and in their effect on increasing player competition time.

Hartig and Henderson, (1999) using 298 military trainees examined static stretching using an intervention and control group. Both groups performed the same stretches prior to exercise.
The intervention group performed the static stretches before lunch, dinner and bedtime, that is, they performed the stretches after exercising. Their results showed that static stretches prior to exercise did not prevent lower extremity overuse injuries, but additional static stretches after training and before bed resulted in 50% fewer injuries occurring. This was one of the only studies to demonstrate that post exercise stretching may have a positive effect on injury prevention.

Calder and Sayer (1992) removed static stretching from the warm-up for the soccer team at the Australian Institute of Sport in 1989. The stretches were replaced with active movements and specific foot and body drills. Static stretching was instead introduced into the soccer players cool down both in post training and post games three times a week. Training injury rates fell significantly in the calves, shins, hamstrings and groin. Hip flexibility improved in flexion and extension by a mean of 20 degrees over the studies four month period (Calder et al 1992). To date no studies have been conducted that have investigated the effect of post exercise stretching on overuse injury prevention in Ironman triathletes.

**2.3.8 Stretching for injury prevention**

Stretching is often used by clinicians in the prevention of overuse injuries (Herbert and Gabriel, 2002). Although it has clinical acceptance there is little reliable research supporting its use (Pope et al 2000). The majority of research into stretching has been in the prevention of traumatic injuries or its effect on delayed onset muscle soreness. The research to date would indicate that stretching has little bearing on traumatic injuries (Pope et al 2000).
Research into stretching for prevention of overuse injuries has mainly been retrospective and inconclusive (Thacker et al 2004). The quality of the research has generally been moderate (Herbert et al 2002), and in some cases has been described as poor (Weldon and Hill 2003). There are some studies that do suggest that stretching has an effect on incidence of injury (Ekstrand et al 1983; Millar, 1976; Godges, MacRae, and Engelke 1993).

Ekstrand et al (1983) showed that a group of soccer players who performed a 20 minute warm-up, including 10 minutes of stretching prior to exercise had only 75% of the injuries when compared to controls. Millar, (1976) found only a 1% reoccurrence rate in patients who had participated in a program involving stretching following a calf tear. This program included strengthening and pain relieving modalities so one cannot attribute the success of this study to stretching alone.

DeVriewe, (1962) showed that stretching had little or no effect on economy of exercise or energy expenditure for running a 100m sprint. This suggests that stretching may be of benefit to certain types of activities but not to others. DeVriewe demonstrated that individuals that were tighter in the trunk and lower extremities were more efficient at several different speeds on the treadmill. Gleim et al (1997) also concluded that subjects who had tighter musculature on testing, were more economical in oxygen consumption for treadmill walking and jogging. This might help to explain Schur’s concept of a difference between stretching abnormally tight tissue into a normal range of motion as opposed to stretching normal tissue into an excessive range (Schur, 2001). By manipulating the muscle tightness in athletes their performance may be improved (Gleim et al (1997), however this has not been related to injury prevention.
This concept of certain stretches being of benefit in some activities and sports and not others was proposed by Witvrouw and others in 2004 (Witvrouw, Mahieu, Daneels and McNair, 2004). Their hypothesis was that sports involving a high-intensity stretch-shortening cycle require a compliant muscle-tendon unit. To maintain or improve this compliance stretching is required to reduce the possibility of tears and injury. In sports that do not have the high-intensity stress on the stretch-shortening cycle such as jogging and cycling, then stretching may be of little benefit. This hypothesis while simplistic may be useful in examining the efficacy and execution of stretching programs in preventing injuries.

Muscular tears have been hypothesized to be caused by weakness in the muscle. Purdham et al (1999) compared the effect of static stretching and ballistic stretching on hamstring strength. The results indicated that a significant reduction of 7% in eccentric hamstring strength was produced by static stretching. The concentric strength of the hamstrings was unaffected by the ballistic or the static stretching. Purdham et al concluded that prolonged static stretching can reduce the eccentric strength of a muscle group immediately post stretching period. This would suggest that static stretching prior to exercise may weaken the muscle and predispose it to injury (Purdham et al 1999). However they did not look at injury rates.

Lally et al (1994) in a review of the Honolulu marathon found that 47 per cent of male runners who stretched prior to training sustained an injury during a one year period, while only 33 per cent of male runners who did not stretch sustained an injury. This difference was statistically significant. In Lally et al’s study an injury was defined as a problem that was
severe enough to disrupt normal training for five days or longer. This effect was not observed in the female runners with stretchers and non-stretchers in the same study (Lally, 1994).

Some authors and athletes believe that stretching can do more harm than good leading to injury (Fixx, 1980). Knapic, Bauman, Jones, Harris and Vaughan, (1991) found that female athletes who had a 15% greater amount of hip extension on the right side were 2.6 times more likely to be injured than those athletes who did not have this imbalance. In these subjects the more flexible side was the most likely to be injured (Knapic et al 1991). This study did not control for poor technique or overstretching that could contribute to the likelihood of injury (Beaulieu, 1981; Anderson, 1988). In contrast Pope et al (2000) found that a reduced flexibility in the calf resulted in a 2.5 times increase in injury risk of the ankle joint.

Thacker et al (2004) proposes that researchers focus on the range of motion or static flexibility that stretching influences and not on the compliance or viscoelasticity of the muscle. The static flexibility is measured using tools such as goniometers to determine joint angles; however the relationship of these measures to dynamic flexibility is unclear (DeVries, 1963). These measuring tools may not be sensitive enough to determine differences that could influence technique, performance, or injury prevention.

Although some people are described as loose or stiff there is little agreement on the definition and limits of normal flexibility (Herbert et al 2003). Of the few comparative studies in the literature few address the multiple potential risk factors and potential confounding variables (Jones et al 1999; Macera, 1992). The area of stretching is a complex one and requires
further research to establish definitions, measuring tools and parameters while considering sport specific demands (Witrouw et al, 2004).
CHAPTER 3

METHODS

3.0 Introduction and overview

This chapter describes the study design, participant recruitment strategy, questionnaire development and structure, and analysis approach undertaken. A literature search was conducted using the following databases: Medline, Embase, CINAHL, SPORTDiscus and PEDro. The key words used in the search included triathlon, ironman triathlon, injury, stretching and prevention.

3.1 Study design

This study was cross-sectional and involved the distribution of a questionnaire (Appendix 1) to all triathletes competing in the Australian Ironman Triathlon Championships race held on the 2nd of April 2006. The questionnaire was designed to obtain information relating to demographics, triathlon preparation and training, injury history and management, and the injury prevention strategies of these athletes. Essentially this study was a stage 1 epidemiological study. Personal interviews at the finish line have been used previously but the amount of information obtained and the rate of participation (6.3%) was very low.
3.2 Participant recruitment

Each entrant in the 2006 Ironman Triathlon received the following in their race registration pack the day before the race: a letter of invitation (Appendix 2) explaining the aims of the study, a copy of the questionnaire, and a reply-paid University-addressed envelope in which to return the completed questionnaire. Consent was implied by completing and returning the questionnaire.

3.3 Human ethics and race organiser approval

Approval was obtained from the Human Research Ethics Committee of the University of Newcastle (Approval No: H-972-0205, Appendix 3). Approval was also obtained from the International Management Group, the organisers and owners of the Australian Ironman Triathlon Championships (Appendix 4), to allow access to the athletes.

In the days leading up to the race the athletes had to register, which involved them attending the race office. They present photographic identification, whereupon they received a pack which contained information concerning the course, rules and flyers from the various corporate sponsors of the race.

This method of recruitment and questionnaire distribution was determined following negotiations with the race organisers. Due to business concerns the organisers were not willing to provide a mailing list or provide contact details of the athletes to the researchers.
The letter of invitation was printed on blue paper to try and attract the attention of the athletes amongst the other sheets of paper in the registration pack. The blue letter of invitation was attached to the questionnaire and the reply-paid envelope. These documents were placed in the pack by the administration volunteers prior to the registration office opening. The participants could complete the questionnaire before or after the race. The questionnaire was returned to the School of Health Sciences, The University of Newcastle, by the triathletes using the provided reply-paid envelope.

3.4 Questionnaire development

The questionnaire was developed following a thorough review of the literature and the determination that there was no suitable alternative instrument available. Some of the questions used were adapted from previously published questionnaires (Egermann et al, 2003, Burns et al 2003) but modified to ensure they were clear and relevant to these athletes. The questionnaire was piloted prior to the race using a small convenience sample (n = 6) of injured triathletes to test its ease of use, content validity and clarity. After piloting, greater use of closed option responses were developed and tables were incorporated to simplify the questionnaire.

3.5 Questionnaire structure

The questionnaire (Appendix 1) consisted of two pages with twenty one questions and covered a number of areas of investigation. The first section contained questions seeking demographic information about the participant. The initial questions requested the participant to indicate their age, gender, height, weight, and history of participation in triathlons and
other sports. The next sections covered the use of coaching and specific injury prevention strategies, such as whether they wore orthotics in their running shoes, or had their bicycle professionally fitted.

Subsequent sections sought information regarding training loads, areas of the body injured, the perceived causes of the injuries, and the persons from whom they sought advice or treatment following injury. These questions provided data regarding the length of time the injuries affected the athlete, the length of time the triathlete had to modify or stop their training, possible contributing factors for the injuries, and the health professionals from whom the athlete sought advice.

The final section questioned the triathlete regarding their stretching habits before and after training and racing, and where they learnt how to stretch. In total there were six sections to the questionnaire.

1 Demographics

2 Training with coach or squad

3 Time off due to injury

4 Training loads

5 Injury sites, management strategies and treating health professional

6 Stretching habits
3.6 Data analysis

Completed questionnaires were returned by mail to the School of Health Sciences at the University of Newcastle. The information was coded where necessary and the data were entered into an Excel spreadsheet (Microsoft® Office Excel 2000). The data were then imported into a statistical program (SPSS® version 13.0 for Windows®) for analysis.

The demographic data obtained from the questionnaires were compared to the race demographic data published by the organisers of the Australian Ironman Triathlon 2006. Comparison of the participants’ gender, age, race performance and years competing in triathlons were made, to help determine whether the respondents were representative of the population of race participants.

Initially, distribution plots and analyses were used to examine the normality of the data and to check for any outlying data points.

Frequency histograms and descriptive statistics were used to obtain an overview of the data before further statistical tests were performed. Further statistical analyses t-tests, $X^2$ tests and analysis of variance (ANOVA) were used to examine the differences between demographic subgroups, as well as various relationships such as:

- Age and injury sites
- Gender and injury sites
- Training loads and injury sites
- Stretching before training and injury sites
- Stretching after training and injury sites.

The results of the statistical analyses are reported in Chapter 4.
CHAPTER 4

RESULTS

4.0 Introduction

The raw data for this study were entered manually from the questionnaires into SPSS for statistical analysis. The data were initially plotted to check for normal distribution and to determine which statistical tests would be appropriate. This chapter will describe the key results from the analysis of the survey data.

4.1 Representative sample

Two hundred and ninety nine questionnaires were returned by respondents. Three of the questionnaires were illegible and unable to be used, leaving two hundred and ninety six questionnaires to be analysed. The total response rate was 24%. The mean age of the participants was 39.2 years with a normal distribution from 18 to 65 years of age, and this was very similar to the age distribution of the race population (Table 4.1). The proportion of male respondents (76%) was almost identical to that of the race population (74%).

<table>
<thead>
<tr>
<th></th>
<th>Sample population</th>
<th>Race population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age in years (SD)</td>
<td>39.2 (9.0)</td>
<td>38.5 (9.4)</td>
</tr>
<tr>
<td>Males (%)</td>
<td>76</td>
<td>74</td>
</tr>
</tbody>
</table>
4.2 Characteristics of race respondents

The mean number of years participating in triathlon competition was 8.2 for the respondents with a range from 0.5 to 30 years (Table 4.2); there were no data available for the race population. The height of the respondents ranged from 150 to 200 cm (normally distributed) with men taller than women (Table 4.2). The weight of the respondents ranged from 47 to 107 kg with men heavier than women. The mean Body Mass Index (BMI) for the respondents was 23.1 kg.m\(^{-2}\). The mean BMI for male respondents was 23.8 kg.m\(^{-2}\) while the BMI for the females was 22.2 kg.m\(^{-2}\) (Table 4.2).

Respondents indicated their previous fastest time for the race using one of four categories. These categories were eight to ten hours, 10.1 to twelve hours, more than twelve hours, and no time posted yet. These categories were chosen to represent elite, sub-elite, non-elites and novice competitors. The results of the 2006 race are presented in Table 4.2.

<table>
<thead>
<tr>
<th>Table 4.2 Characteristics of respondents. Data are mean (SD) or percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
</tr>
<tr>
<td>Number</td>
</tr>
<tr>
<td>Age (yrs)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>BMI (kg.m(^{-2}))</td>
</tr>
<tr>
<td>Triathlon years</td>
</tr>
<tr>
<td>Time for race</td>
</tr>
<tr>
<td>8-10 hours</td>
</tr>
<tr>
<td>10.1-12 hours</td>
</tr>
<tr>
<td>12.1-14 hours</td>
</tr>
<tr>
<td>&gt;14 hours</td>
</tr>
</tbody>
</table>
Respondents were asked of their best previous Ironman triathlon race time. The results of this question are presented in Table 4.3. The sub-elite group had the greatest representation with 147 respondents (49.7% of the total number of respondents).

<table>
<thead>
<tr>
<th>Time</th>
<th>Males N (%)</th>
<th>Females N (%)</th>
<th>Total N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elite (8-10 hrs)</td>
<td>25 (11.4)</td>
<td>3 (3.9)</td>
<td>28 (9.5)</td>
</tr>
<tr>
<td>Sub-elite (10.1-12 hrs)</td>
<td>122 (55.6)</td>
<td>25 (32.5)</td>
<td>147 (49.7)</td>
</tr>
<tr>
<td>Novice (&gt;12 hrs)</td>
<td>38 (17.4)</td>
<td>39 (51.0)</td>
<td>77 (26.0)</td>
</tr>
<tr>
<td>No time posted</td>
<td>34 (15.6)</td>
<td>10 (12.6)</td>
<td>44 (14.8)</td>
</tr>
</tbody>
</table>

4.2.1 Gender differences

There were no significant differences between the mean ages of the men and women or the number of years they had been competing in triathlons. Men had a faster time for completing the race with 11.4% completing the race in 8-10 hours (elite category) compared to 3.9% of women completing the race in 8-10 hours. A greater proportion of men finished the race in 10.1-12 hours compared to the women surveyed. Most of the women (63.1%) completed the race in 12 hours or more. These differences in the completion times for men and women were significant (P = 34.87, p=0.000).
4.2.2 Respondents’ competitive sport before triathlon

This question was asked to gain an understanding of the sporting history of the athletes prior to commencing triathlon. In total, forty different sports were listed by respondents prior to commencing participation in triathlon, although 14.8% of the respondents did not list a sport. The most common sport prior to triathlon was running, followed by swimming, and a number of team sports (Table 4.4). Few athletes cycled for sport prior to commencing triathlon racing. The prior sport had no significant relationship with the time for completion of the race (P=179.96, p = 0.31).
Table 4.4 Competitive sports respondents participated in prior to triathlon racing

<table>
<thead>
<tr>
<th>Prior competitive sport</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasion games</td>
<td>82</td>
<td>30.8</td>
</tr>
<tr>
<td>Running</td>
<td>55</td>
<td>20.7</td>
</tr>
<tr>
<td>No sport listed</td>
<td>36</td>
<td>14.8</td>
</tr>
<tr>
<td>Swimming</td>
<td>27</td>
<td>10.2</td>
</tr>
<tr>
<td>Other Water sports</td>
<td>27</td>
<td>10.2</td>
</tr>
<tr>
<td>Striking/Fielding sports</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Other sports</td>
<td>7</td>
<td>2.6</td>
</tr>
<tr>
<td>Net/Court games</td>
<td>7</td>
<td>2.6</td>
</tr>
<tr>
<td>Cycling</td>
<td>6</td>
<td>2.3</td>
</tr>
<tr>
<td>Martial arts</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Dance</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Target sports</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Other endurance sports</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>266</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Key to Table 4.4

**Invasion games** include: basketball, netball, soccer, rugby league, rugby union, AFL, touch football, hockey, gaelic football

**Net/court games** include: tennis, squash, badminton, volleyball

**Other endurance sports** include: cross country skiing

**Other water sports** include: sailing, surf lifesaving, surfing, rowing, waterpolo

**Striking/field sports** include: cricket, baseball, softball

**Martial arts** include: boxing, martial arts

**Dance** includes: classical ballet, gymnastics

**Target sports** include: snooker, golf

**Other sports** include: equestrian, skateboarding, body building, motorbike racing, skiing.
4.3 Training characteristics

Women swam more per week in training than men (Table 4.5). Women also cycled and ran more per week than men. Females spent more time strength training than the males, but there was no significant difference between the time spent on stretching between males and females (Table 4.5).

**Table 4.5** Gender differences in training loads of Ironman triathletes.

Data are presented as mean (SD) hours per week.

<table>
<thead>
<tr>
<th></th>
<th>Male N=220</th>
<th>Female N=75</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swimming</td>
<td>3.5 (0.1)</td>
<td>4.3 (0.2)</td>
<td>T=-3.57, p=0.00</td>
</tr>
<tr>
<td>Cycling</td>
<td>8.5 (0.2)</td>
<td>10.2 (0.4)</td>
<td>T=-3.83, p=0.00</td>
</tr>
<tr>
<td>Running</td>
<td>4.5 (0.1)</td>
<td>5.1 (0.2)</td>
<td>T=-2.14, p=0.03</td>
</tr>
<tr>
<td>Strength training</td>
<td>0.8 (1.1)</td>
<td>1.1 (1.3)</td>
<td>F=4.53, p=0.03</td>
</tr>
<tr>
<td>Stretch training</td>
<td>1.1 (1.0)</td>
<td>1.2 (1.1)</td>
<td>F=0.55, p=0.46</td>
</tr>
<tr>
<td>Other sports</td>
<td>0.8(0.9)</td>
<td>0.6(0.8)</td>
<td>F=1.1, p=0.32</td>
</tr>
</tbody>
</table>

The mean (SD) time spent in other sports each week was 0.66 (0.9) hours with a range of 0 to 20 hours.

4.4 Stretching

Two hundred and twenty-five of the athletes who occasionally, rarely or never stretched before training formed 76.7% of the respondents (Table 4.6). This indicates that only 23.3% of the respondents stretched regularly prior to training. One hundred and sixty-five of the
respondents stretched occasionally, rarely or never after training which is 56% of the sample population. One hundred and twenty-nine respondents stretched always or mostly after training, comprising 43.5% of the sample population (Table 4.7).

**Table 4.6** Regularity of stretching before training

<table>
<thead>
<tr>
<th></th>
<th>Always</th>
<th>Mostly</th>
<th>Occasionally</th>
<th>Rarely</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>25</td>
<td>44</td>
<td>48</td>
<td>109</td>
<td>68</td>
</tr>
<tr>
<td>%</td>
<td>8.4</td>
<td>14.9</td>
<td>16.2</td>
<td>36.8</td>
<td>23.0</td>
</tr>
</tbody>
</table>

The mean (SD) time that athletes held their stretches was 24 (20) seconds with a range of 1 to 60 seconds. Seventy-two percent of respondents stated that 30 seconds was how long they held their stretches, with 15 seconds the next most frequently stated time to hold stretches (Table 4.8). The mean (SD) number of times that respondents performed their stretches was 2.55 times and the median was 2 with 124 (41.9%) respondents.

**Table 4.7** Regularity of stretching after training

<table>
<thead>
<tr>
<th></th>
<th>Always</th>
<th>Mostly</th>
<th>Occasionally</th>
<th>Rarely</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>46</td>
<td>83</td>
<td>68</td>
<td>77</td>
<td>20</td>
</tr>
<tr>
<td>%</td>
<td>15.5</td>
<td>28.0</td>
<td>23.0</td>
<td>26.0</td>
<td>6.8</td>
</tr>
<tr>
<td>Mean (SD) total injuries</td>
<td>2.03 (1.4)</td>
<td>1.84 (1.4)</td>
<td>2.41 (1.6)</td>
<td>2.61 (1.7)</td>
<td>1.64 (1.04)</td>
</tr>
</tbody>
</table>
The respondents were asked to tick the areas of the body they stretched. A free-text option was left for them to nominate any other areas that were not on the checklist provided. The most commonly stretched areas were the hamstrings (n=263, 88.9%), calf (n=262, 88.5%), and quadriceps muscles (n=255, 86.1%). The stretched areas are listed in Table 4.10. The areas of the body were stretched by both genders equally and there was no statistically significant relationship between the age of the athlete and the areas of the body that were stretched (t=1.2, p=0.35).

<table>
<thead>
<tr>
<th>Repetition number</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>28</td>
<td>9.5</td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>10.5</td>
</tr>
<tr>
<td>2</td>
<td>124</td>
<td>41.9</td>
</tr>
<tr>
<td>3</td>
<td>84</td>
<td>28.4</td>
</tr>
<tr>
<td>4-10</td>
<td>21</td>
<td>7.0</td>
</tr>
<tr>
<td>11+</td>
<td>1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Table 4.9 Number of times respondents performed stretches

<table>
<thead>
<tr>
<th>Time held (s)</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>13</td>
<td>4.4</td>
</tr>
<tr>
<td>1-10</td>
<td>61</td>
<td>20.7</td>
</tr>
<tr>
<td>11-20</td>
<td>87</td>
<td>29.4</td>
</tr>
<tr>
<td>21-30</td>
<td>87</td>
<td>29.4</td>
</tr>
<tr>
<td>31-60</td>
<td>36</td>
<td>12.2</td>
</tr>
<tr>
<td>61+</td>
<td>5</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Table 4.8 Time respondents held their stretches
Table 4.10 Body areas stretched by respondents

<table>
<thead>
<tr>
<th>Body area stretched</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamstrings</td>
<td>263</td>
<td>88.9</td>
</tr>
<tr>
<td>Calf</td>
<td>262</td>
<td>88.5</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>255</td>
<td>86.1</td>
</tr>
<tr>
<td>Groin/hip</td>
<td>205</td>
<td>69.3</td>
</tr>
<tr>
<td>Buttocks</td>
<td>187</td>
<td>63.2</td>
</tr>
<tr>
<td>Lower back</td>
<td>182</td>
<td>61.5</td>
</tr>
<tr>
<td>Shoulders</td>
<td>158</td>
<td>53.4</td>
</tr>
<tr>
<td>Neck</td>
<td>94</td>
<td>31.8</td>
</tr>
<tr>
<td>Upper back</td>
<td>94</td>
<td>31.8</td>
</tr>
<tr>
<td>Iliotibial band</td>
<td>23</td>
<td>7.8</td>
</tr>
<tr>
<td>Achilles</td>
<td>14</td>
<td>4.7</td>
</tr>
<tr>
<td>Triceps/biceps</td>
<td>6</td>
<td>2.1</td>
</tr>
<tr>
<td>Abdominals</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td>Feet</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td>Hip flexors</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td>Chest</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Forearms</td>
<td>1</td>
<td>0.3</td>
</tr>
</tbody>
</table>
4.5 Resources listed by respondents to learn stretches

The respondents were asked where they learnt their stretches. In addition to five listed options, an additional ‘other’ option was included with space for a written response. Health professionals provided advice on stretching in 99 instances, with a combination of health professionals, coaches, books and magazines producing information to a further 89 of the respondents. The other responses included courses attended, university, school, and fitness professionals other than coaches (Table 4.11).

Table 4.11 Resources listed by respondents to learn stretches

<table>
<thead>
<tr>
<th>Resources</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health professional</td>
<td>99</td>
<td>33.4</td>
</tr>
<tr>
<td>Combination</td>
<td>89</td>
<td>30.1</td>
</tr>
<tr>
<td>Coach</td>
<td>30</td>
<td>10.1</td>
</tr>
<tr>
<td>Magazine/book</td>
<td>26</td>
<td>8.8</td>
</tr>
<tr>
<td>Other</td>
<td>24</td>
<td>8.1</td>
</tr>
<tr>
<td>None listed</td>
<td>16</td>
<td>5.4</td>
</tr>
<tr>
<td>Athlete</td>
<td>11</td>
<td>3.7</td>
</tr>
<tr>
<td>Video/DVD</td>
<td>1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

4.6 Coaching

4.6.1 Triathlon coach

Just over a third of the respondents (n=108, 36.5%) used a triathlon coach for guidance in their training. A greater percentage of women had a triathlon coach (50%) than the men in the study sample (31.8%). Respondents who used a triathlon coach swam more with a mean (SD) of 4.23 (1.2) hours per week versus 3.39 (1.1) hours per week for the remainder of the sample (t (296)=3.93, p=0.00), cycled more per week with a mean (SD) of 10.06 (5.4) hours per
week versus 8.36 (4.8) hours per week (t(296)=4.24, p=0.000), and ran more per week with a mean (SD) of 5.29 (1.7) hours per week versus 4.31 (1.2) hours per week (t(296)=4.06, p=0.000).

Athletes did more strength training per week with a triathlon coach with a mean (SD) of 1.08 (0.5) hours versus 0.71 (0.5) hours (t(296)=2.67, p=0.01). Having a triathlon coach made no difference to the amount of time spent stretching per week with a mean (SD) of 1.12 (0.6) hours per week with a triathlon coach versus 1.14 (0.5) without a triathlon coach (t(296)=-0.179, p=0.86).

4.6.2 Swim coach

Of the respondents, 18.2% used a swim coach (n=54): 17.7% of males and 19.7% of the females in the study. The amount of time spent swimming per week was not influenced by the respondent having a swimming coach ($X^2=0.88$, p=0.39).

4.6.3 Cycle coach

Of the respondents, only six (2.1% of the population) had a cycle coach: four males (1.8% of males) and two females (2.6% of females). The amount of time spent cycle training was not influenced by having a cycle coach (t=1.36, p=0.23).

4.6.4 Running coach

Of the respondents, only six used a running coach (2.1%): four males (1.8% of males) and two females (2.6% of females). Respondents with a running coach demonstrated a trend towards spending more time running per week (t=1.88, p=0.12).
4.7 Training squads

4.7.1 Triathlon squad

The respondents were part of a triathlon squad in 74 cases (25%), with 52 males (23.6% of males) and 22 females (28.9% of females). Triathlon squad members had significantly less time that they were unable to train due to injury (t=2.73, p=0.01), and had a trend to modify their training less although this was not a significant relationship (t=1.51, p=0.13). Orthotics and a professional bike fit were more likely to be used by triathlon squad members compared to the rest of the sampled population ($X^2=3.16$, p=0.07).

The time to complete the race was not significantly influenced by being part of the triathlon squad ($X^2=2.15$, p=0.54). The amount of swimming, cycling and running training was not influenced by being in a triathlon squad (t=0.02, p=0.99). Similarly, being a member of a triathlon squad made no significant difference to the amount of time spent stretching or strengthening (t=1.12, p=0.27).

4.7.2 Swim squad

Of the respondents, 69 were part of a swim squad (23.3%) with 51 males (23.2% of males) and 18 females (23.7% of females). The amount of time spent swimming was not affected by a respondent being a member of a swim squad (t=0.22, p=0.98). Respondents in a swim squad stretched before and after training to a similar degree as the non-swim squad respondents ($X^2=5.57$, p=0.23). The amount of time a stretch was held and the number of times a stretch was repeated were not affected by being part of a swim squad (t=0.17, p=0.86; t=0.98, p=0.33 respectively).
4.7.3 Cycle squad

Of the respondents in the study, 24 were part of a cycle squad (8.1%) with 21 males (9.5% of males) and three females (3.9% of females). The amount of time spent cycle training was not significantly affected by being part of a cycle squad (t=0.14, p=0.89). Cycle squad respondents spent a similar amount of time performing strengthening and stretching exercises as the rest of the sample population (t=1.16, p=0.26; t=0.68, p=0.60 respectively).

Respondents in the cycle squad stretched before they trained to a similar degree as the non-cycle squad respondents (t=0.89, p=0.38). There was a trend for cycle squad respondents to be more likely to stretch after training but this was not significant (t=1.79, p=0.08). The amount of time a stretch was held was significantly less for the cycle squad respondents (t=2.42, p=0.02). Respondents who were members of a cycle squad did not repeat their stretches any differently to the non-cycle squad members (t=0.58, p=0.56).

4.7.4 Running squad

Of the respondents in the study, 25 were part of a running squad (8.4%) with 21 males (9.5% of males) and four females (5.3% of females). The amount of time the running squad members spent running trended lower than non-running squad members but this was not significant (t=1.69, p=0.10). There was also a trend for the running squad members to perform less strength training hours per week (t=1.66, p=0.11). Running squad respondents did not stretch any more or less than the rest of the sampled population (t=0.93, p=0.36) and were no more or less likely to wear orthotics ($X^2=1.32, p=0.25$). The time to complete the race was not significantly affected by being a member of a running squad ($X^2=2.45, p=0.48$). The amount of time a stretch was held was significantly more for the running squad respondents (t=2.95, p=0.003). The number of times a stretch was repeated was not affected by being part of a running squad (t=2.09, p=0.84).
4.7.5 Other squads

In the category of other squads, 20 respondents (6.8%) stated that they trained with friends and two respondents (0.7%) went on group cycle rides but did not define the group.

4.8 Bike fitting

Question eight in the questionnaire asked respondents whether they had had their bicycle professionally fitted. Of the respondents in the study, 197 had had their bike professionally fitted (66.6%), with 139 males (63.2% of males) and 58 females (76.3% of females). Women were more likely to have their bike professionally fitted (P=4.38, p=0.04). A professional bike fit did not appear to influence time to complete the race (P=2.03, p=0.57).

Bike fit respondents were significantly more likely to hold their stretches for longer (t=1.82, p=0.05) with a mean (SD) of 25 (2.1) seconds compared to 21 seconds for the rest of the sample. Bike fit respondents did not stretch before they trained any differently to the rest of the sample population (t=2.51, p=0.64). The bike fit respondents demonstrated a trend to stretching more after training (t=7.40, p=0.12), and performing more repetitions of their stretches (t=1.54, p=0.13) but neither was statistically significant.

An athlete’s prior sport did not determine whether they had their bicycle professionally fitted (P=65.36, p = 0.21) unless they cited cycling as the prior sport. Triathletes who listed their prior sport as cycling had their bike fitted in 75% of cases.
4.9 Injuries

4.9.1 Injury incidence

The incidence of non-traumatic injuries in the triathletes was 2.38 per 1000 hours of training. The formula for this calculation was:

\[
\text{Incidence rate} = \frac{\text{Number of injuries reported}}{\text{x 1000}}/(\text{No. of Respondants x total hours of training in a season}).
\]

4.9.2 Injured body areas

Question fourteen examined the site of injuries, the cause to which the athlete attributed the injury, the health professional from whom they sought treatment, and the treatment they considered was most beneficial. In order of frequency, the most injured area of the body was the knee (n=104), followed by the lower back (n=101), and the ankle/foot (n=91), with the other body regions listed in Table 4.12.

There was a gender difference with men more likely to experience lower back injuries (males 37.3%, females 25.0%), which was statistically significant (P=3.79, p=0.05). There was a slight trend for males to experience more knee injuries than females (males 36.8%, females 30.3%), however this was not statistically significant (P=1.07, p=0.30). Females were more likely to experience hip/buttock/groin injuries (females 35.5%, males 23.2%), which was statistically significant (P=3.82, p=0.05). Females were more likely to experience head and neck injuries (females 26%, males 15.4%), although this did not quite reach statistical significance (P=3.50, p=0.06). Similarly, females were more likely to experience shoulder/arm injuries (females 30.0%, males 21.4%), but this was also not statistically significant (P=2.48, p=0.12).
Table 4.12 Frequency of injured body areas

<table>
<thead>
<tr>
<th>Injured body area</th>
<th>N</th>
<th>Males (%)</th>
<th>Females (%)</th>
<th>Total (%)</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee</td>
<td>104</td>
<td>36.8</td>
<td>30.3</td>
<td>35.1</td>
<td>1</td>
</tr>
<tr>
<td>Lower back</td>
<td>101</td>
<td>37.3</td>
<td>25.0*</td>
<td>34.1</td>
<td>2</td>
</tr>
<tr>
<td>Ankle/foot</td>
<td>91</td>
<td>31.8</td>
<td>27.6</td>
<td>30.7</td>
<td>3</td>
</tr>
<tr>
<td>Hips/buttock/groin</td>
<td>78</td>
<td>23.2</td>
<td>35.5*</td>
<td>26.4</td>
<td>4</td>
</tr>
<tr>
<td>Shoulder/arm</td>
<td>70</td>
<td>21.4</td>
<td>30.0</td>
<td>23.6</td>
<td>5</td>
</tr>
<tr>
<td>Head/neck</td>
<td>53</td>
<td>15.4</td>
<td>25.0*</td>
<td>17.9</td>
<td>6</td>
</tr>
<tr>
<td>Calf</td>
<td>52</td>
<td>17.7</td>
<td>17.1</td>
<td>17.6</td>
<td>7</td>
</tr>
<tr>
<td>Shin</td>
<td>36</td>
<td>11.8</td>
<td>13.2</td>
<td>12.2</td>
<td>8</td>
</tr>
<tr>
<td>Thigh</td>
<td>26</td>
<td>7.7</td>
<td>11.2</td>
<td>8.8</td>
<td>9</td>
</tr>
<tr>
<td>Upper back</td>
<td>16</td>
<td>5.5</td>
<td>5.3</td>
<td>5.4</td>
<td>10</td>
</tr>
<tr>
<td>Wrist/hand</td>
<td>10</td>
<td>3.2</td>
<td>3.9</td>
<td>3.4</td>
<td>11</td>
</tr>
<tr>
<td>Chest/abdomen</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0.7</td>
<td>12</td>
</tr>
</tbody>
</table>

* Denotes significant gender difference (p < 0.05)

4.9.3 Attributed causes of injury

The respondents were asked to attribute causes for their injuries. The responses of the respondents are listed in Table 4.13. The three most frequently reported attributed causes for each body area/region are listed. Excess training was the leading attributed cause for injury in seven out of the twelve areas. In two other areas excess training was the second leading cause for injury. The triathletes did not list which activity they were overtraining in. Poor technique has the most cited cause in two areas (head/neck and shoulder/arm) and was the second or third most frequent cause for injury in four other areas (wrist/hand, lower back, hips/buttock/groin, and thigh). Old shoes and poor bike set-up were the next most commonly reported causes contributing to injury. Falls were frequently reported for wrist and chest
injuries; however these might be related to traumatic injuries, whereas the present study focused on overuse injuries.

**Table 4.13** Attributed causes of injury in various areas of the body

<table>
<thead>
<tr>
<th>Injured body area</th>
<th>N</th>
<th>Leading cause</th>
<th>%</th>
<th>Second cause</th>
<th>%</th>
<th>Third cause</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee</td>
<td>104</td>
<td>Excess training</td>
<td>39.7</td>
<td>Running</td>
<td>11.5</td>
<td>Old shoes</td>
<td>10.3</td>
</tr>
<tr>
<td>Lower back</td>
<td>101</td>
<td>Excess training</td>
<td>23.6</td>
<td>Poor technique</td>
<td>19.4</td>
<td>Poor bike set-up</td>
<td>9.7</td>
</tr>
<tr>
<td>Ankle/foot</td>
<td>91</td>
<td>Excess training</td>
<td>43.3</td>
<td>Old shoes</td>
<td>21.7</td>
<td>Running</td>
<td>16.7</td>
</tr>
<tr>
<td>Hips/buttock/groin</td>
<td>78</td>
<td>Excess training</td>
<td>47.3</td>
<td>Poor technique</td>
<td>10.9</td>
<td>Running</td>
<td>7.3</td>
</tr>
<tr>
<td>Shoulder/arm</td>
<td>70</td>
<td>Poor technique</td>
<td>46.4</td>
<td>Excess training</td>
<td>17.9</td>
<td>Falls</td>
<td>16.1</td>
</tr>
<tr>
<td>Head/neck</td>
<td>53</td>
<td>Poor technique</td>
<td>30.3</td>
<td>Poor bike set-up</td>
<td>18.2</td>
<td>Excess training</td>
<td>15.2</td>
</tr>
<tr>
<td>Calf</td>
<td>52</td>
<td>Excess training</td>
<td>43.9</td>
<td>Running</td>
<td>19.5</td>
<td>Old shoes</td>
<td>12.2</td>
</tr>
<tr>
<td>Shin</td>
<td>36</td>
<td>Running</td>
<td>36.5</td>
<td>Excess training</td>
<td>25.8</td>
<td>Old shoes</td>
<td>12.9</td>
</tr>
<tr>
<td>Thigh</td>
<td>26</td>
<td>Excess training</td>
<td>47.1</td>
<td>Running</td>
<td>23.5</td>
<td>Poor technique</td>
<td>5.9</td>
</tr>
<tr>
<td>Upper back</td>
<td>16</td>
<td>Excess training</td>
<td>20.0</td>
<td>Posture</td>
<td>20.0</td>
<td>Poor bike set-up</td>
<td>20.0</td>
</tr>
<tr>
<td>Wrist/hand</td>
<td>10</td>
<td>Falls</td>
<td>57.1</td>
<td>Poor technique</td>
<td>14.3</td>
<td>Excess training</td>
<td>14.3</td>
</tr>
<tr>
<td>Chest/abdomen</td>
<td>2</td>
<td>Surgery</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**4.10 Influence of time in previous Ironman triathlons on injury**

The number of injuries sustained by respondents in the different race time categories were not statistically significant (F=1.05, p=0.373). The category that had the highest number of injuries was the 12+ hours group with a mean (SD) of 2.36 (1.5) injuries. The lowest number of injuries was reported by respondents in the 10.1-12 hours category with a mean (SD) of 2.01 (1.4) injuries (Table 4.14).
Table 4.14 Total injuries and time to complete race previously

<table>
<thead>
<tr>
<th>Group</th>
<th>N(%)</th>
<th>Mean injuries</th>
<th>SD</th>
<th>95% lower bound</th>
<th>95% upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 – 10 hours</td>
<td>28(9.5)</td>
<td>2.32</td>
<td>2.3</td>
<td>1.4</td>
<td>3.2</td>
</tr>
<tr>
<td>10.1 – 12 hours</td>
<td>147(49.7)</td>
<td>2.01</td>
<td>1.4</td>
<td>1.8</td>
<td>2.3</td>
</tr>
<tr>
<td>12.1 hours +</td>
<td>77(26.0)</td>
<td>2.36</td>
<td>1.5</td>
<td>2.0</td>
<td>2.7</td>
</tr>
<tr>
<td>No time yet</td>
<td>44(14.8)</td>
<td>2.14</td>
<td>1.4</td>
<td>1.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Total</td>
<td>296(100)</td>
<td>2.13</td>
<td>1.6</td>
<td>1.9</td>
<td>2.3</td>
</tr>
</tbody>
</table>

4.11 Training loads and injuries

4.11.1 Swimming hours

The mean (SD) time spent swim training each week was 3.7 (2.8) hours with a range of 0 to 15 hours. The amount of time the athletes spent swimming per week was not significantly associated with the number of injuries in the shoulder/arm (t (296)=0.173, p=0.86), head and neck (t (296)=0.06, p=0.95) or the lower back regions (t (296)=0.09, p=0.93).

4.11.2 Cycling hours

The mean (SD) time spent cycle training each week was 9.0 (4.7) hours with a range of 0 to 21 hours. There was no significant relationship between cycle hours and the incidence of lower back pain in the respondents (t=0.68, p=0.50), cycle hours and the incidence of knee pain in the respondents (t=0.38, p=0.73).

4.11.3 Running hours

The mean (SD) time spent run training each week was 4.7 (7.5) hours with a range of 0 to 20 hours. The hours an athlete ran was significantly associated with shin injuries (t=2.22, p=0.03). Runners with shin injuries had a mean (SD) of 5.8 (4.6) hours of running per week.
compared to athletes without shin pain who ran for a mean (SD) of 4.5 (4.4) hours per week. The occurrence of hip/buttock/groin injuries in athletes who ran more per week (mean of 5.1 (4.0) hours) while not statistically significant, demonstrated a trend (t=1.72, p=0.09). Athletes with a hip/buttock/groin injury ran for a mean (SD) of 5.0 (3.3) hours per week compared to 4.5 (3.4) hours per week for those without shin injuries. The other body areas and total injuries did not demonstrate any significant relationships or trends.

**4.11.4 Strength training hours**

The mean (SD) time spent strength training each week was 0.85 (1.2) hours with a range of 0 to 7 hours. Ankle/foot injuries were significantly related to the amount of strength training performed per week (t=2.83, p=0.005). The mean (SD) time for strength training for athletes with an ankle/foot injury was 1.15 (1.6) hours per week, compared to 0.7 hours per week for athletes without an ankle/foot injury. There also appeared to be a weak relationship between the number of hours spent strength training per week and the total number of injuries, although this was not statistically significant (P= 0.11, p=0.07). Injuries in other parts of the body were not related to the amount of time the athlete spent strength training (Table 4.15).

**4.11.5 Stretching hours**

The mean (SD) time spent stretching each week was 1.1 (1.3) hours with a range of 0 to 7 hours. There was a significant relationship between the amount of time spent stretching each week and the total number of injuries (P=0.17, p=0.003). That is, the hours stretched each week was positively correlated with the total number of injuries. The amount of time the athlete stretched was also related to the number of knee injuries they sustained (t=2.00, p=0.05). The mean (SD) time the knee injured athletes spent stretching per week was 1.3 (0.8) hours compared to 1.0 (0.9) hours for those without knee injuries.
There was a trend for respondents with shin injuries to spend more time stretching ($t=1.60$, $p=0.11$), with shin injured athletes spending a mean (SD) of 1.4 (1.1) hours per week stretching compared to 1.1 (1.1) hours per week for those without shin injuries. No other injured body area was associated with the amount of time spent stretching per week (Table 4.15).
Table 4.15 Strength training and stretch training relationships to injured body areas

<table>
<thead>
<tr>
<th>Injured body area</th>
<th>Strengthening</th>
<th></th>
<th>Stretching</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t value</td>
<td>p value</td>
<td>t value</td>
<td>p value</td>
</tr>
<tr>
<td>Ankle</td>
<td>2.83</td>
<td>0.005*</td>
<td>0.09</td>
<td>0.93</td>
</tr>
<tr>
<td>Calf</td>
<td>1.35</td>
<td>0.18</td>
<td>0.88</td>
<td>0.38</td>
</tr>
<tr>
<td>Hip/buttock/groin</td>
<td>1.13</td>
<td>0.26</td>
<td>0.41</td>
<td>0.69</td>
</tr>
<tr>
<td>Knee</td>
<td>0.53</td>
<td>0.60</td>
<td>2.00</td>
<td>0.047*</td>
</tr>
<tr>
<td>Lower back</td>
<td>0.96</td>
<td>0.34</td>
<td>1.09</td>
<td>0.28</td>
</tr>
<tr>
<td>Shin</td>
<td>0.95</td>
<td>0.35</td>
<td>1.60</td>
<td>0.11</td>
</tr>
<tr>
<td>Shoulder/arm</td>
<td>0.79</td>
<td>0.43</td>
<td>1.44</td>
<td>0.15</td>
</tr>
<tr>
<td>Upper back</td>
<td>0.54</td>
<td>0.60</td>
<td>1.38</td>
<td>0.17</td>
</tr>
</tbody>
</table>

* Denotes statistical significance < 0.05

4.11.6 Time in other sports and injury

The amount of time the triathlete spent in another sport had no significant association with injury. The previous sport that a triathlete had listed also had no relationship with injury.

4.11.7 Unable to train due to injury

Question eleven asked respondents how long they were unable to train for in the last twelve months due to injury (Table 4.16). Of the respondents, 153 (51.7%) were unable to train for some period of time during the last twelve months; 121 males (55% of males) and 32 females (42.1% of females). For males, the range of days unable to train was 1 to 360 days with a mean (SD) of 20.9 (32.1) days. Sixteen male respondents were unable to train for 70 days or more. For females the range of days unable to train was 0 to 210 days with a mean (SD) of
13.0 (11.0) days. Thirteen female respondents were unable to train for 14 days or more. This difference between males and females while not statistically significant, suggested a difference (t=1.67, p=0.10).

Table 4.16 Days unable to train

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>121</td>
<td>20.9</td>
<td>32.1</td>
</tr>
<tr>
<td>Females</td>
<td>32</td>
<td>13</td>
<td>11</td>
</tr>
</tbody>
</table>

4.11.8 Modified training due to injury

Question twelve asked the triathletes how long they had to modify their training in the last twelve months due to injury (Table 4.17). Of the respondents, 165 had to modify their training for a period of time during the last twelve months with a gender distribution of 131 males (59.5% of males) and 34 females (44.7% of females). For males, the range of days for modifying training was 0 to 360 days with a mean (SD) of 36.4 (24.3) days. Twelve male respondents had to modify training for 150 days or more. For females, the range of days of modified training was 0 to 360 days with a mean (SD) of 39.3 (28.6) days. Twelve female respondents had to modify training for 90 days or more. There was no statistically significant difference between males and females in days of training modification (t=0.30, p=0.77).
Table 4.17 Days that athletes had to modify their training

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>131</td>
<td>36.4</td>
<td>24.3</td>
</tr>
<tr>
<td>Females</td>
<td>34</td>
<td>39.3</td>
<td>28.6</td>
</tr>
</tbody>
</table>

4.11.9 Influence of coaching on injuries

Employing a triathlon coach made no significant difference to the amount of time the athletes could not train due to injury (t (296) = -1.07, p=0.29) nor to the time athletes had to modify their training due to injury (t (296) = -0.63, p=0.53). Those triathletes with a triathlon coach tended to having more injuries (t (296)=1.88, p=0.06) than those who did not, but this was not statistically significant.

Those with a swim coach demonstrated a trend towards having more time being unable to train due to injury (t=1.56, p = 0.12), but there was no association with having to modify training (t=0.75, p = 0.45). Those with a swim coach had a greater proportion of shoulder injuries ($X^2=3.54, p=0.05$); 15 shoulder injuries out of 54 athletes with a swim coach (27.8%) versus 55 shoulder injuries out of 242 athletes without a swim coach (22.8%). Upper back injuries were less likely with a swim coach with only 1.9% of swim coached athletes having an upper back injury as opposed to 6.2% of the athletes without a swim coach, and this difference was significant ($X^2=2.85, p=0.05$).

A cycle coach made no significant difference to the amount of time training had to be modified due to injury (t=0.49, p = 0.62), or the amount of time the athlete was unable to train (t=1.30, p = 0.20). No athlete with a cycle coach reported a lower back injury whereas 101 (34.1%) of the athletes without a cycle coach had a lower back injury. This was not statistically significant but demonstrated a strong trend (P=3.1, p = 0.08).
A running coach did not influence the time the athlete was unable to train due to injury (t=1.34, p=0.89), or the amount of time they had to modify their training (t=1.08, p=0.33). Of the athletes that had a running coach only one had a knee injury (16.7% of the running coach sample) whereas those without a running coach had 103 knee injuries representing 35.5% of the remaining sample ($X^2=0.92$, $p=0.05$). A run coach made no difference to the occurrence of calf injuries ($X^2 = 0.00$, $p=1.00$) or shin injuries ($X^2=0.95$, $p=0.33$). Triathletes with running coaches were more likely to use orthotics ($X^2=4.18$, $p=0.04$).

4.11.10 Influence of training in a squad on injuries

The total number of injuries the athletes sustained was not affected by being in a triathlon squad (t=0.41, $p=0.68$). Stretching before (t=1.51, $p=0.83$), stretching after (t=6.90, $p=0.14$), the number of repetitions (t=0.51, $p=0.61$) and the length of time the stretch was held (t=1.00, $p=0.32$) were not significantly related to triathlon squad participation.

The amount of time spent swimming was not associated with a shoulder or upper back injury ($X^2=0.56$, $p=0.46$). Lower back injury was no more likely in the swim squad respondents ($X^2=1.38$, $p=0.24$). The total number of injuries was not significantly related to being part of a swim squad (t=1.10, $p=0.27$).

The amount of time the cycle squad respondents were unable to train due to injury was significantly higher than for non-cycle squad respondents (t=1.98, $p=0.05$). The amount of time cycle squad respondents had to modify their training due to injury was not significant (t=1.27, $p=0.22$). Neck, upper back, lower back and shoulder injuries were not different for cycle squad respondents to the remainder of the sample ($X^2=0.00$, $p=1.00$; $X^2=0.00$, $p=1.00$; $X^2=0.01$, $p=0.93$; $X^2=0.01$, $p=0.93$ respectively).
There was a trend for cycle squad respondents to be more likely to suffer from a knee injury, however this was not significant ($X^2=2.34$, $p=0.13$). The total number of injuries that cycle squad respondents experienced was not significantly different from the rest of the sample population ($t=-0.34$, $p=0.74$).

The amount of time running squad members were unable to train or had to modify their training due to injury was not significantly different to the remainder of the sample ($t=1.36$, $p=0.19$; $t=1.14$, $p=0.26$ respectively). There was no significant difference between the prevalence of lower back injuries in the running squad compared to the rest of the sampled population ($X^2=0.06$, $p=0.82$). There was a slight but non-significant trend towards more knee injuries in running squad members ($X^2=1.49$, $p=0.22$). The number of hip/buttock/groin ($X^2=0.04$, $p=0.85$), calf ($X^2=0.11$, $p=0.74$), shin ($X^2=0.01$, $p=0.98$) and ankle/foot injuries ($X^2=0.58$, $p=0.45$) were not dissimilar to the remainder of the sampled population. The total number of injuries in the running group respondents was not significantly different to that of the remaining sampled population ($t=-0.18$, $p=0.86$). Respondents in the running squad stretched before they trained ($t=3.05$, $p=0.55$), and stretched after they trained to a similar degree as the non running-squad respondents ($t=3.39$, $p=0.50$).
4.12 Influence of prevention strategies on injuries

4.12.1 Bikefit

A professional bike fit had no significant influence on the amount of time the athletes were unable to train due to injury (t=0.351, p=0.73), however there was a trend for respondents with a bikefit to modify their training due to injury (t=1.52, p=0.13). A professional bike fit had a significant association with hip/buttock/groin injuries.

The proportion of bike fit respondents that reported a hip/buttock/groin injury was 35.1%, over twice that for the non-bike fit respondents (16.2%) (P=7.20, p=0.007).

Having a bike fit appeared to have no relationship with the incidence of head and neck injuries (P=0.05, p=0.82). Other injured parts of the body that were not related to having a professional bike fit included the shoulder (P=0.07, p=0.79), upper back (P=0.01, p=0.94), lower back (P=0.01, p=0.94), knee (P=0.03, p=0.85), calf (P=0.13, p=0.72) and shin (P=0.04, p=0.84). There was a trend for athletes who had a professional bike fit to experience more injuries with a mean (SD) of 2.24(1.2) injuries compared to 1.94(0.88) for the rest of the sample, however this was not statistically significant (P=1.66, p=0.10).

Bike fit respondents were significantly more likely to hold their stretches for longer (t=1.82, p=0.05) with a mean (SD) of 25(2.3) seconds compared to 21(2.0) seconds for the rest of the sample. Bike fit respondents did not stretch before they trained any differently to the rest of the sample population (t=2.51, p=0.64). The bike fit respondents demonstrated a trend to stretching more after training (t=7.40, p=0.12), and performing more repetitions of their stretches (t=1.54, p=0.13) but neither was statistically significant.
4.12.2 Orthotics

Question nine in the questionnaire asked respondents whether they used orthotics in their running shoes. Of the respondents in the study, 105 had orthotics in their running shoes (35.5%), with 75 males (34.1% of males) and 30 females (39.5% of females). Respondents who used orthotics were not significantly different in the number or site of injuries to other respondents (Table 4.18), however there was a trend towards more hip/buttock/groin injuries (P=2.59, p=0.11).

Those respondents wearing orthotics were not significantly different to the other respondents in the time that they held their stretches (t=1.02, p=0.40) or the number of times they repeated the stretches (t=-1.13, p=0.26). The athletes that had orthotics did not show any difference in stretching before training (P=0.74, p=0.95), however they stretched after training far more than the non-orthotic respondents (P=13.67, p=0.008). The orthotic wearers included 51.3% stretching ‘mostly and always’ after training, compared to 46.3% in the non-orthotics group. The orthotic group had only 19% stretching ‘rarely or never’ compared to 31.1% in the non-orthotic group (Table 4.19).
Table 4.18 Orthotic wearers and injured parts of the body

<table>
<thead>
<tr>
<th>Body area</th>
<th>Pearson Chi-Square</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle/foot</td>
<td>0.72</td>
<td>0.40</td>
</tr>
<tr>
<td>Calf</td>
<td>0.11</td>
<td>0.74</td>
</tr>
<tr>
<td>Hip/buttock/groin</td>
<td>2.59</td>
<td>0.11</td>
</tr>
<tr>
<td>Knee</td>
<td>0.1</td>
<td>0.92</td>
</tr>
<tr>
<td>Lower back</td>
<td>1.37</td>
<td>0.24</td>
</tr>
<tr>
<td>Shin</td>
<td>0.41</td>
<td>0.52</td>
</tr>
<tr>
<td>Shoulder/arm</td>
<td>1.53</td>
<td>0.22</td>
</tr>
<tr>
<td>Total injuries</td>
<td>1.01</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Table 4.19 Use of orthotics and frequency of stretching after training

<table>
<thead>
<tr>
<th></th>
<th>Stretching after training N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Never</td>
</tr>
<tr>
<td>Orthotics</td>
<td>0(0)</td>
</tr>
<tr>
<td>No orthotics</td>
<td>13(4.4)</td>
</tr>
</tbody>
</table>
Figure 4.1 Mean of total injuries and frequency of stretching after training
4.13 Health professionals consulted

Of the twelve injured body areas, physiotherapists were reported to be the most sought after health professionals for ten areas. Medical practitioners were the next most consulted health professionals, followed by chiropractors. A summary of the results can be viewed in Table 4.20.

Table 4.20 Health professionals the respondents consulted for injured body areas in order of frequency consulted

<table>
<thead>
<tr>
<th>Injured body area</th>
<th>N</th>
<th>Leading professional</th>
<th>%</th>
<th>Second professional</th>
<th>%</th>
<th>Third professional</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee</td>
<td>104</td>
<td>Physiotherapist</td>
<td>39.7</td>
<td>Medical practitioner</td>
<td>13.2</td>
<td>Masseur</td>
<td>10.3</td>
</tr>
<tr>
<td>Lower back</td>
<td>101</td>
<td>Physiotherapist</td>
<td>30.4</td>
<td>Masseur</td>
<td>17.4</td>
<td>Chiropractor</td>
<td>10.1</td>
</tr>
<tr>
<td>Ankle/foot</td>
<td>91</td>
<td>Physiotherapist</td>
<td>32.8</td>
<td>Medical practitioner</td>
<td>10.3</td>
<td>Medical practitioner &amp; physiotherapist</td>
<td>8.6</td>
</tr>
<tr>
<td>Hips/buttock/groin</td>
<td>78</td>
<td>Physiotherapist</td>
<td>29.1</td>
<td>Masseur</td>
<td>12.7</td>
<td>Masseur &amp; physiotherapist</td>
<td>12.7</td>
</tr>
<tr>
<td>Shoulder/arm</td>
<td>70</td>
<td>Physiotherapist</td>
<td>39.1</td>
<td>Medical practitioner</td>
<td>10.9</td>
<td>Masseur</td>
<td>10.9</td>
</tr>
<tr>
<td>Head/Neck</td>
<td>53</td>
<td>Physiotherapist</td>
<td>31.0</td>
<td>Chiropractor</td>
<td>17.2</td>
<td>Chiropractor</td>
<td>17.2</td>
</tr>
<tr>
<td>Calf</td>
<td>52</td>
<td>Physiotherapist</td>
<td>25.7</td>
<td>Masseur</td>
<td>20.0</td>
<td>Medical practitioner &amp; physiotherapist</td>
<td>8.7</td>
</tr>
<tr>
<td>Shin</td>
<td>36</td>
<td>Physiotherapist</td>
<td>34.8</td>
<td>Masseur physiotherapist</td>
<td>13.0</td>
<td>Medical practitioner &amp; physiotherapist</td>
<td>8.7</td>
</tr>
<tr>
<td>Thigh</td>
<td>26</td>
<td>Masseur</td>
<td>29.4</td>
<td>Physiotherapist</td>
<td>11.8</td>
<td>Medical practitioner</td>
<td>11.8</td>
</tr>
<tr>
<td>Upper back</td>
<td>16</td>
<td>Physiotherapist</td>
<td>62.5</td>
<td>Chiropractor</td>
<td>25.0</td>
<td>Masseur</td>
<td>12.5</td>
</tr>
<tr>
<td>Wrist/hand</td>
<td>10</td>
<td>Physiotherapist</td>
<td>40.0</td>
<td>Medical practitioner</td>
<td>40.0</td>
<td>Masseur</td>
<td>20.0</td>
</tr>
<tr>
<td>Chest/abdomen</td>
<td>2</td>
<td>Medical practitioner</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.14 Management strategies for injuries

In all twelve injured body areas, treatment was stated as the most common strategy that the respondents found effective in managing their injuries. Treatment was defined as intervention from a health professional. Rest and/or rest combined with treatment were the second most
common strategies that respondents found helpful. Rest was defined as ceasing all sporting activity and training. The respondents found that changing training was useful in four injured areas, and for one area the respondents listed rest, treatment and changing treatment as the third most used strategy in thigh injuries.
<table>
<thead>
<tr>
<th>Injured body area</th>
<th>N</th>
<th>Leading strategy</th>
<th>%</th>
<th>Second strategy</th>
<th>%</th>
<th>Third strategy</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee</td>
<td>104</td>
<td>Treatment</td>
<td>33.3</td>
<td>Rest &amp; treatment</td>
<td>18.8</td>
<td>Rest</td>
<td>12.5</td>
</tr>
<tr>
<td>Lower back</td>
<td>101</td>
<td>Treatment</td>
<td>45.3</td>
<td>Rest &amp; treatment</td>
<td>28.0</td>
<td>Rest</td>
<td>8.0</td>
</tr>
<tr>
<td>Ankle/foot</td>
<td>91</td>
<td>Treatment</td>
<td>30.6</td>
<td>Rest &amp; treatment</td>
<td>29.2</td>
<td>Rest</td>
<td>13.9</td>
</tr>
<tr>
<td>Hips/buttock/groin</td>
<td>78</td>
<td>Treatment</td>
<td>58.6</td>
<td>Rest &amp; treatment</td>
<td>17.2</td>
<td>Change training</td>
<td>8.6</td>
</tr>
<tr>
<td>Shoulder/arm</td>
<td>70</td>
<td>Treatment</td>
<td>33.3</td>
<td>Rest</td>
<td>21.6</td>
<td>Rest &amp; treatment</td>
<td>15.7</td>
</tr>
<tr>
<td>Head/neck</td>
<td>53</td>
<td>Treatment</td>
<td>51.5</td>
<td>Rest</td>
<td>18.2</td>
<td>Change training</td>
<td>9.1</td>
</tr>
<tr>
<td>Calf</td>
<td>52</td>
<td>Treatment</td>
<td>30.8</td>
<td>Rest &amp; treatment</td>
<td>25.6</td>
<td>Rest</td>
<td>15.4</td>
</tr>
<tr>
<td>Shin</td>
<td>36</td>
<td>Treatment</td>
<td>21.1</td>
<td>Rest &amp; treatment</td>
<td>14.3</td>
<td>Change training</td>
<td>10.7</td>
</tr>
<tr>
<td>Thigh</td>
<td>26</td>
<td>Treatment</td>
<td>66.7</td>
<td>Rest &amp; treatment</td>
<td>22.2</td>
<td>Rest &amp; change training</td>
<td>5.6</td>
</tr>
<tr>
<td>Upper back</td>
<td>16</td>
<td>Treatment</td>
<td>72.7</td>
<td>Rest</td>
<td>27.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist/hand</td>
<td>10</td>
<td>Treatment</td>
<td>42.9</td>
<td>Rest</td>
<td>14.3</td>
<td>Change training</td>
<td>14.3</td>
</tr>
<tr>
<td>Chest/abdomen</td>
<td>2</td>
<td>Rest</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 5

DISCUSSION

5.1 Introduction

The training loads, injury patterns and stretching habits of two hundred and ninety six participants of the 2006 Australian Ironman Triathlon were examined in this study. The key findings of this study were:

- The mean total training load was 19.5 hours per week
- The incidence of non-traumatic injury was 2.38 per 1000 hours of training
- Excess training was the most frequently attributed cause of injury but there was no significant association between overall training load and injuries
- The most injured site was the knee comprising 35.1% of the total injuries
- There was a gender difference in the injuries the respondents sustained
- The more time an athlete spent running the more likely they were to have experienced a shin injury
- Being a member of a triathlon squad was associated with less time the athlete had to modify their training due to injury
- Stretching before training had no significant relationship with injuries, whereas stretching after training was inversely related to injuries
- The more an athlete was injured the more time they spent stretching
- Physiotherapists were the most consulted professionals for injuries
- Health professional treatment and rest were the most common injury management strategies.
5.1.1 Discussion overview

First the characteristics of Ironman triathletes are discussed in regards to age, gender, socioeconomic status, anthropometry, and prior sports participation. This is followed by discussion of training loads and the use of coaching, as well as injury prevention measures such as having a professional bike fit or wearing orthotics. The triathletes’ injuries including sites and contributing factors are also discussed. Finally, the role that stretching may play in the management and prevention of injuries is examined.

5.2 Characteristics of respondents

5.2.1 Gender, age and socioeconomic status

The study population appears to be representative of the overall race population. The gender distribution was 76% male in the study compared with 74% in the race population, which is typical in Ironman triathlons (O’Toole et al 1989) and triathlons of other distances.

Ironman Australia requires that all athletes are 18 years or older, consequently the Ironman Triathlon tends to attract older participants compared to the shorter course triathlons which allow junior participants from the age of 6 years of age. The mean age of the respondents in this study was 39.2 years, similar to the mean age of the entire race population of 38.5 years. Egermann et al (2003) reported a mean age of 35.8 years in Ironman Europe triathletes and Burns et al (2003) reported a mean age of 33.7 years in their study of Australian Ironman triathletes. In contrast, the mean age for the national short course Australian triathlon is 24 years (Patterson 2008). Triathlon Australia recommends that junior athletes start on short courses, and as they increase in age so the distances in which they compete may increase.
This is to firstly make the races achievable and inviting for junior athletes, and secondly to ensure a margin of safety from injury for their developing bodies.

Moreover, to compete in Ironman events requires significant money; the entry fee is $750 whereas the entry fee for short course triathlons ranges from $20 to $250. The mean income of participants in the 2007 World Ironman Championships was AUD $185,000. This suggests that the Ironman triathlon is a sport that attracts athletes of higher socioeconomic status. The socioeconomic status of Australian Ironman triathletes has not yet been reported in the literature.

5.2.2 Height, weight and BMI

The height and weight of the triathletes in this study were collected as self-reported data. The tallest athlete was 200cm while the shortest was 150cm. The weight of the athletes ranged from 47 to 107kg. No comparison with the race population can be made as the organisers of the Australian Ironman Triathlon do not include other participant characteristic questions in their registration process.

The mean BMI for athletes was 23.1 kg.m\(^{-2}\) which places most participants in the desirable healthy range (World Health Organisation, 2000), with males (23.8 kg.m\(^{-2}\)) higher than females (22.2 kg.m\(^{-2}\)). This compares to a BMI of 22.5kg.m\(^{-2}\) in the study by Egermann et al (2003) of the participants in the 2000 Ironman Europe triathlon. The difference in BMI with gender is likely explained primarily by a difference in muscle mass (Egermann et al 2003). Massimino et al (1988) used the height and weight of participants in the 1985 Hawaii Ironman Triathlon to calculate their Quetelet Index (weight x 100/height\(^2\)). They concluded
that the respondents were lighter than the general population. Van Gent et al (2007) found that male runners with a BMI of 27.0 or higher had fewer injuries.

5.2.3 Respondents’ competitive sport before triathlon

The sports the participants listed that they participated in prior to triathlon were largely a reflection of common sports in Australia. In total, forty sports were listed. The main sports were all codes of football and running. The previous sport did not appear to have any relationship with performance or injuries.

5.3 Training characteristics

5.3.1 Training loads

The training loads reported are very similar to that in the published literature. Egermann et al (2003) in their review of Ironman triathletes found they had a mean (SD) training load of 15.7 (5.8) hours per week. Similar to this study, Egermann et al (2003) did not find any association between training load and performance or injury. Collins et al (1989) also did not find a relationship between training loads and incidence of injury. Although there does not appear to be a link between injury and training loads, O’Toole et al (1989) in a review of the World Ironman Championships remarked that measuring intensity of training in a self-reported survey is very difficult. Shaw et al (2004) in the examination of triathletes from all distances found that the triathletes who trained the least and the triathletes who trained the most had a greater number of injuries, whereas the remaining athletes had less. They described this as a ‘U’ shaped relationship. We did not see any evidence of this in our study,
however in this study we were only reporting on Ironman triathletes whereas Shaw and colleagues were reporting on triathletes from all distances (Shaw et al 2004).

5.3.2 Differences between male and female training loads

In the triathlon literature there has been very little information published regarding the relationship of gender to training load (Massimino et al 1988). In the present study, women trained more frequently and longer hours per week than men in all three disciplines. Massimino et al (1988) in a study of the 1985 Hawaii Ironman Triathlon similarly found that women had greater training loads in swimming and running as did O’Toole et al (1989). They concluded that this may have reflected a greater commitment to the sport. Differences in available time, career demands and opportunity for training and racing may have been other factors.

5.3.3 Coaching

Although the sport of triathlon involves three disciplines, instead of using a coach for each discipline triathlon coaches covering all three have become available. This is because in recent years accredited triathlon coaching courses have become available. This allows athletes to use just the one coach instead of a separate coach for each discipline. This appears to be reflected in the higher percentage of triathlon coached athletes (36.5%) versus the use of coaches in the other three disciplines (36.5% employed a triathlon coach, 18.2% a swimming coach and 2% cycling and running coaches). This may be important as the swimming demands in a triathlon are different to pool swimming. In Ironman triathlon triathletes have to raise their head frequently to ensure they stay on target. They also do not have a wall to push
off and regularly swim in salt water with higher buoyancy than pools. These factors while accepted in the triathlon community have yet to be researched and their implications examined.

5.3.4 Triathlon coach

Of the total respondents, 36.5% made use of a triathlon coach, with 50% of women employing such a coach but only 31.8% of men. Athletes who had a triathlon coach had greater training loads per week in all three disciplines. Having a triathlon coach was also associated with the triathlete performing more strength training. On the other hand, employing a triathlon coach did not appear to affect the amount of time a triathlete spent stretching. Having a triathlon coach did not seem to affect performance or injury rate.

5.3.5 Swimming coach

If a triathlete in this study had a swim coach they were more likely to report a shoulder injury, although the amount of time spent swim training per week was no greater than those without a swim coach. This may suggest that the training intensity or swimming drills performed with a swimming coach may have an effect on shoulder injuries. Alternatively, triathletes may seek out a swimming coach if they have problems with shoulder injuries. Further research is required to examine this result.

Cipriani (1998) states that the demands of triathlon swimming are different to those of traditional swimming, and that there needs to be a change in training philosophy by the swimming coaches of triathletes. It was not asked in the present study whether a respondent’s swim coach was accredited or whether they had experience with the demands of triathlon
swimming. Interestingly, the incidence of upper back injuries in athletes with a swim coach were significantly lower than for athletes without a swim coach \( (X^2=2.85, \ p=0.05) \). This finding has not been reported previously and may be related to feedback on stroke and correcting technical faults.

5.3.6 Cycling coach

Only six of the respondents had a cycling coach. This represents only 2% of the respondents, which limits the conclusions that can be made and is surprising considering that the largest component of the Ironman triathlon is the cycling leg. The use of a cycling coach in Ironman triathlon is not reported in the literature. Triathlon coaches tend to include cycling coaching in their programs. Neither training load nor modification due to injury was related to having a cycling coach. What was of note is that none of the respondents with a cycling coach reported a lower back injury, whereas of the remaining 290 respondents 50% reported a lower back injury. Other studies have identified that cycling load is associated with lower back injury (Cipriani et al 1998; Burns et al 2003). This area requires further investigation but it may suggest that having a cycling coach could reduce the likelihood of a lower back injury, with better management of training loads and/or better feedback on technique.

5.3.7 Running coach

Of the respondents only six (2%) reported using a running coach. Of these six only one reported a knee injury (16.7% of the running coach group), whereas the remaining 290 athletes suffered 103 knee injuries (35.5% of the remaining study population). This difference was statistically significant and suggests that a running coach may be able to reduce injury.
The six athletes with a running coach were also more likely to have orthotics and this was statistically significant when compared to the remaining study population. Of the six athletes who wore orthotics there did not appear to be an association with the frequency of lower limb injuries, with these athletes reporting similar calf, shin and ankle injuries to the remaining population. However due to the cross-sectional nature of this study, one cannot conclude whether the orthotics were preventative or a treatment.

5.4 Training squads

The athletes were asked whether they were part of a training squad. These squads were then broken down in to triathlon squads or squads for each individual leg of the triathlon. Being a member of a squad seemed to relate to a reduced amount of training time lost to injury. Egermann et al (2003) examined the influence of a coach on injury but not whether being part of a squad had any effect. The literature has not reported this factor to date. This may be a topic worthy of further research.

5.4.1 Triathlon squad

Seventy-four percent of the respondents were in a triathlon squad, with a slightly higher female distribution (23.6% of all male respondents, 28.9% of all female respondents). Being a member of a triathlon squad was associated with less time off training due to injury, but modifying training due to injury more often. One interpretation may be that when an athlete was injured the triathlon squad may have offered different levels of difficulty and the athlete was able to choose an easier level while recovering. However, these respondents had the same training loads as the rest of the sample population and had the same number of injuries.
This would suggest that while being part of a triathlon squad does not prevent injuries, it may allow the athlete to manage their training more effectively during recovery. Other studies to date in this field have either not asked this question, or all the athletes sampled were part of a triathlon squad (Vleck et al 1998). This may also allow the triathlete to better maintain their fitness and maintain or improve their performance.

5.4.2 Swimming squad

Of the respondents, 69 (23%) were members of a swimming squad. Being a member of a swimming squad did not appear to be associated with the training loads, injury rates or stretching habits of these athletes. However it was not asked how often the athlete attended the swimming squad, as it may not have had a significant effect on their training if they only attended once a week or sporadically. Another question for further investigation is whether the swimming coach was giving specific training for the triathletes with respect to their races or whether the triathletes performed the same training as the other swimmers who rarely race longer than 1500m (the swim in Ironman triathlons is 3800m).

5.4.3 Cycling squad

In this study, 24 (8%) of the respondents reported being part of a cycling squad. Males were more strongly represented (10% of males, 4% of females). The cycling training load was not related to being a member of a cycling squad, however the amount of time the cycling squad respondents were unable to train due to injury was significantly higher than for the rest of the triathletes in the study. This may have been due to more traumatic injuries in the squad as cycling in groups has been associated with increased traumatic injuries (Guichon et al 1975).
Although the hours spent training were no different, the intensity of training in a squad may be higher and sudden increases in training intensity may be more likely to cause injury than the training duration, as suggested by O’Toole et al (1989) and Williams et al (1988).

5.4.4 Running squad

The running squad respondents consisted of 21 males (9.5%) and 4 females (5.3%), which comprised 8.4% of total respondents. There was a trend for these respondents to spend less time running per week. There was also a trend to perform less strength training per week in this group. There did not appear to be any significant relationship between being a member of a running squad and injuries.

5.5 Injury incidence

The incidence of non-traumatic injury in this sample population was 2.38 per 1000 hours of training. This is much higher than that reported by Egermann et al (2003), who found an overall injury incidence of 0.71 per 1000 hours of exposure in Ironman triathletes when both traumatic and non-traumatic injuries were included. In the present study only non-traumatic injuries were investigated, although it is likely that a small number of the injuries reported were a consequence of trauma. It was therefore expected that the injury incidence in this study would be lower than that reported by Egermann et al (2003). It is hard to provide an explanation for this difference. However compared to that reported for other sports in Australia (football 20.3/1000 hr, field hockey 15.2/1000 hr, basketball 15.1/1000 hr and netball 12.1/1000 hr), the injury rate in this study was considerably lower at 2.38/1000 hr (Stevenson et al 2000).
5.5.1 Specific injured areas of the body

The different parts of the body were listed for the athletes and they were asked to indicate the areas they had injured in the past twelve months (Table 4.2). In the present study the knee was the most frequently injured body part, although the lower back was a close second. In the studies by Egermann et al (2003) and O’Toole et al (1989) of Ironman triathletes, the back was the most frequently injured part of the body. Cipriani et al (1998) reported the knee the most frequently injured part of the body, with 25% of their sample reporting problems in this area, with the foot/ankle/achilles a near second at 24%. In the present study, 31% of the respondents reported an ankle/foot injury and this was the third most injured body area. In the study by O’Toole et al (1989) the reported percentages for those areas were much higher with 72% of the athletes reporting back pain and 84% reporting a knee injury over a twelve month period. Conversely, the rates reported by Burns et al (2003) were much lower, with 15% of their sample reporting lower back injury and 17% an injury of the knee. Notably, Burns et al (2003) had the smallest sample (n=96) of all of these studies and interviewed people directly after the race. All the other studies used a paper-based questionnaire and this may have some bearing on the differences in data obtained.

Although there is a marked variation in injury rates between these studies, the knee and lower back are consistently stated to be the most commonly injured sites. This has implications for further research and for educating physiotherapists and other health professionals, particularly to assist them in the prevention and management of injury in these athletes. The use of the hamstrings and quadriceps in a limited range of motion on the cycle and then trying to use the same muscles to run over a greater range of motion may have a bearing on
the knee injuries. The tightness in the muscles following the cycle may place greater stress on the patellofemoral joint resulting in pain. This requires further research.

The present study asked athletes to report any injury to the hip/buttock/groin area, and over a quarter (26%) of the athletes reported injuries in this area making it the fourth most commonly reported injury site. This has not been reported in the triathlon injury literature to date and may warrant further attention. However it is reported in both the running and cycling literature (van Gent et al 2007; Sanner and O’Halloran, 2000). In recent times core stability has become an area of interest both to physiotherapists and exercise scientists, notably core muscle endurance and core muscle control. In the future, a prospectively designed study with tests of lumbopelvic instability and examining the incidence and/or predictors of injury in triathletes may be of benefit.

5.5.2 Gender differences in injury

The two main injury sites that demonstrated a gender bias were the lower back (males 37%, females 25%) and the hip/buttock/groin (males 23%, females 36%). Vleck et al (1998) also found that males sustained lower back injuries more frequently than females. Sanner and O’Halloran (2000) found greater hip and pelvis overuse injuries in women in cycling and attribute it in part to the increased Q angle. Interestingly, other authors have not found a gender difference in injuries (Burns et al 2003; Cipriani et al 1998; Collins et al 1989; O’Toole et al 1989). However, the proportion of females in these studies was quite low with Egermann et al (2003) only reporting 10% of respondents as female and yet typically 25% of the racing population is female. The higher incidence of lower back injuries is often attributed to less flexibility in males (Egermann et al 2003; O’Toole et al 1989). Future research may benefit from performing flexibility tests on the athletes and then following them
over a period of time. Injuries in the hip/buttock/groin area may also be influenced by bicycle design and set-up (Pruitt et al 2006). Certain bicycle companies are now marketing female specific bike designs. It would be interesting to determine whether there was an association between using these bikes and injuries in the hip/buttock/groin area in women.

Females in our study also had a strong trend to more neck injuries (females 26%, males 15%), and while not statistically significantly different to males due to the small total number of neck injuries, this is reported to be a common reason for female triathletes seeking a professional bike set-up (Hogg, 2008; Wisbey-Roth, 2008). Of interest would be an investigation of whether there is a relationship between the anthropometrics of female cyclists, their injuries and the measurements of their bicycles.

5.5.3 Attributed causes of injury

The respondents attributed a cause for each injury they had listed. Excess training was considered the leading cause of injury in seven of the twelve anatomical areas of injury listed. The lower limb and back were the most commonly cited areas associated with excess training. In two other areas (ankle/achilles and hip/buttock/groin) excess training was reported as the second leading cause for injury. Burns et al (2003) found running the leading cause for lower limb injury in Ironman triathletes, as did O’Toole et al (1989). However the respondents in our study did not cite running but rather excess training, although there was no significant association between training load and injury. This excess training may be more related to the intensity rather than duration of training. This may also be a triathlete perception over fact. Further detailed investigation taking into account other parameters of training such as terrain, work to rest ratios and intensity may give an answer to this problem.
Poor technique was the most cited cause of injury in the upper limb and head and neck regions, and is mentioned in four other areas as the second or third cause of injury (wrist/hand, lower back, hips/butt/groin, and thigh). How the athletes realised they had poor technique needs to be examined, and was this in running, swimming or running? Was this information concerning poor technique obtained from a coach, other training partners or a perception by the triathletes themselves? Old shoes and poor bike set-up are the next most reported causes contributing to injury. Yet there is little evidence in the data and literature with respect to shoe wear and injury. The shock absorption involved in running one would think has an influence on overuse injuries, but would require a controlled study with force platforms to determine the effect of shoes on lower limb injuries. Evidence for correct bike set-up in influencing comfort and lower back pain is strong (Salai, et al 1999), however it needs to be examined further with regards to performance. Falls are reported for wrist and chest injuries; however this is presumably related to traumatic injuries, whereas this study was focusing on overuse injuries.

Egermann et al (2003) in their study of the Ironman Europe Triathlon Race found that training had a significant relationship to injury. They reported that cycling caused the majority of injuries, accounting for 55% of the injuries reported in their sample. However Egermann et al (2003) did not differentiate between hip/butt/groin and lower back areas, which may explain why in the present study the other part of the body that demonstrated an associative trend was the hip/buttock/groin area. Clearer and confident differentiation of injury sites in further studies may help to clarify this. In this study, if you combine the lower back data and the hip/butt/groin data you get quite a large injury percentage (179 injuries, 24.5% of the total number of injuries).
5.5.4 Participant characteristics and injury

Body Mass Index did not relate to injury site or rate. Massimino et al in 1988 did not state whether the Quetelet Index they calculated had an association with injury. In the present study, if we had hypothesised that a higher BMI might place greater loads on the athlete’s body and result in a higher injury rate or a higher rate of injury in the lower limbs when running. However Van Gent et al (2007) found that male runners with a BMI of 27.0 or higher had fewer injuries. This was not evident in the data from this study.

There were only two subjects who had a BMI in excess of 30kg.m\(^{-2}\). The highest BMI was 37.0kg.m\(^{-2}\), a 39 year old male who had experienced an ankle/foot injury which he attributed to old shoes. Jacques (2007) suggests that the larger the athlete the sooner they will collapse the midsole of a running shoe and with the lack of shock absorption, place themselves at greater risk of injury. The lowest BMI reported was 16.9kg.m\(^{-2}\) in a 34 year old female. This particular athlete reflected the low BMI associated with the female athlete triad and may have had reduced bone density. Interestingly, this participant also reported an ankle/foot injury, which she attributed to running. The treatment strategy she used was rest, orthotics and consulting a podiatrist. This would suggest that factors other than weight may have been responsible for the incidence of injuries in some triathletes.

5.5.5 Time to complete the race

The time to complete the race did not have a significant relationship with injury rate or site, which is consistent with the findings of Vleck et al (1998), but differs to Korkia et al (1994) and Shaw et al (2004) who did find a relationship between injury rate and time to complete
the race. However Egermann et al (2003) similarly suggested that there was no significant relationship between the performance level of the athlete and overuse injury, but did find a relationship to traumatic injuries. Egermann et al (2003) explained their findings by proposing that higher performance athletes may take greater risks and travel at a higher velocity. Higher performance athletes also have a greater exposure to racing and this increase in intensity was proposed to be a factor (Egermann et al 2003). Risk taking may have a greater impact on traumatic injury, however in the present study the focus was on non-traumatic injuries. One could also argue that more elite triathletes move more efficiently and therefore can perform more training with less likelihood of injury.

The sport the respondent participated in prior to starting triathlon racing was recorded to determine whether it had an association with injury rate or site of injury. On review of the literature this has been briefly mentioned but not investigated (Cipriani et al 1998; Massimino et al 1988; Migliorini et al 2000; O’Toole et al 1989). The sports identified had no significant association with injury rate or site.

5.4.6 Training hours and injury

The mean time athletes in this study trained per week was 19.5 hours. The slightly greater number of hours reported in the study by O’Toole et al (1989) of 20.7 hours per week may have been because the participants were competing in the World Championship in Ironman Triathlon and the athletes would likely be training at maximum effort. The athletes at the World Championship would be of a more elite level and prepared to sacrifice other activities to compete at this level. More research needs to be conducted to verify this.
A relationship between training load and injuries has been found in some studies (O’Toole et al, 1989) but not in others (Burns et al 2003; Cipriani et al 1998; Collins et al 1989; Egermann et al 2003). In the present study, it was found that there was no significant relationship between swimming hours or cycling hours with the total number of injuries or injuries in any specific part of the body. However the hours an athlete ran was significantly associated with the incidence of shin injuries. Athletes with shin injuries had a mean weekly running load of 5.75 hours, whereas other athletes without shin injuries had a mean of 4.5 hours running load per week. These data are supported by findings from Ireland et al (1987) and O’Toole et al (1989). Both these studies found that running load was the leading attributed cause of lower limb injuries. However in a more recent study, Egermann et al (2003) did not find a relationship between running and lower limb injury. Indeed their study found that cycling training was the leading cause of lower limb and lower back injury. However the athletes surveyed in Egermann et al (2003) were predominantly German and this region in known for having a strong bias for cycling compared to other countries and they trained more in cycling than the Australian Ironman triathletes. This may explain the difference, but needs to be investigated further.

5.4.7 Strength and stretch training effects on injury

The athletes were asked how much time per week they performed strengthening and stretching training. The athletes who reported ankle/foot injuries spent more time strength training with a weekly mean of 1.2 hours per week, compared to 0.7 hours per week for the rest of the sample population. This may be because if they were unable to perform their normal training due to injury they may have supplemented their training regime with resistance training. The athletes who reported more time strength training had a strong trend towards having more injuries generally. Although not statistically significant, this may be a
training strategy or it might be that the strength training is part of their rehabilitation, or it could be part of their overload of training. There was also a significant relationship between the amount of time an athlete stretched and the number of injuries they reported. This relationship needs to be explored further to determine whether stretching is a contributing factor to injury or whether stretching is used as a management strategy for injury.

There were some associations between specific sites of injury and the amount of time the athletes stretched. The incidence of knee injuries was related to the time athletes held their stretches. Furthermore, the more stretching an athlete performed the more likely they were to report a knee or shin injury. Further investigation in this area is needed to determine whether stretching contributes to injury or is simply used in rehabilitation. The motivation behind the stretching needs to be determined in further studies.

In the present study women trained more than men. This increased training load was not associated with an increased injury rate or the site of injury. This may have been influenced by the fact that women spent significantly more time strength training per week (women 1.09 hr/week, men 0.76 hr/week), which may have had an injury prevention effect.

5.4.8 Coaching and injury

Egermann et al (2003) did not find any significant relationship between injury and having a coach. This variable has not been examined in any of the other literature concerning Ironman triathletes. Indeed, in our study having a coach was not related to incidence of injury. Employing a triathlon coach also did not appear to be associated with the amount of time the athlete had to modify their training or stop training due to injury. This area was examined as
triathletes may be looking to these coaches for greater intensity, help them manage their training load better, or for their better understanding of periodisation.

5.6 Prevention strategies and injury

5.6.1 Bikefit

In recent years biomechanists have been involved in measuring athletes and fitting the bicycle to them (Asplund et al 2004; Capelli et al 1993; Cosca et al 2007). This process is still an emerging science and there are different approaches to the task. Respondents were not asked to indicate the approach they used, but simply to state if their bicycle had been professionally fitted to them. Of the 296 respondents, 197 (66.6%) had had their bike professionally fitted (63% of males, 76% of females). These athletes cycled more per week and spent more time strength training per week than the other triathletes.

The bike fit respondents had a significantly higher proportion of hip/buttock/groin injuries (35% versus 16% for the non-bikefit group). In a personal communication to one of the more recognised bike fitting technicians in Sydney, he reported a high proportion of injuries in the hip/buttock/groin area in his clients, and that this was the main reason for the triathletes using his services (Hogg et al 2008; Wisbey-Roth et al 2008). This may also explain why athletes who had a bike fitted had a mean of 2.24 total injuries compared to the rest of the sample with 1.94. This finding might suggest that these triathletes primarily sought a bike fit as a treatment strategy and less for performance enhancement or injury prevention. It would be interesting to follow-up these athletes to determine if the bike fit helped to manage their injury or prevent recurrence. These triathletes may also have experienced a performance improvement if the discomfort they had on the bicycle was reduced by having a professional
bike fit. This is of interest as there are many clinics in Australia and overseas that provide bike fitting. Triathletes were more likely to state that they had their bike professionally fitted if they had listed cycling as a previous competitive sport. There is no industry standard for bike fitting and this may have caused some confusion in the questionnaire.

5.6.2 Orthotics

Of the respondents in this study, 36% wore orthotics in their running shoes. There was no significant difference in the site or number of injuries in athletes who wore orthotics, although there was a trend towards more hip/butt/groin injuries. The lack of a significant relationship between injury and orthotic use would tend to agree with several other papers where runners have been studied (Hreljac et al, 2000; Khodaee et al, 2011). There was a significant relationship between orthotic wearers and stretching after training. It should be determined in future studies whether orthotics are being used as a treatment tool or a prevention strategy.

5.7 Treatment sought

5.7.1 Health professionals

Of the twelve injured sites, physiotherapists were listed as the primary health professional consulted in ten of the twelve areas. Of the remaining two areas where other professionals were consulted, physiotherapists were rated second in one of these areas. The health professionals consulted by athletes other than physiotherapists were masseurs, medical practitioners, podiatrists and chiropractors. A basic knowledge of the Ironman triathlon and the stresses it places on an athlete’s body should be understood by all of these practitioners to
better treat and manage the athlete’s injuries. A summary of the most injured body areas on the Triathlon Australia website (www.triathlon.org.au) for health professionals and triathletes may be of benefit.

5.7.2 Injury management strategies

In eleven out of the twelve injured areas treatment by physiotherapists was reported as the most utilised strategy for management of the respondents’ injuries. Rest with and without treatment was the next most commonly listed strategy. This likely relates to a perception of excess training, which was stated as a contributing factor in seven of the twelve areas. Poor technique was also prominent in the reported causes and yet not one athlete listed biomechanical analysis or technique modification as part of their injury management. The questionnaire was not specific enough to capture this information. However biomechanical analysis and/or technique modification may have been part of their treatment program with the health professionals, but the triathletes may not have recognised it. It would be interesting to survey a range of health professionals who have regular contact with these athletes and determine whether they include technique modification in their treatment regime.

Athletes listed a change of training as a treatment strategy. Considering that physiotherapists were the most sought after professional, these athletes would likely have been given advice regarding changes to training. This would suggest that information regarding the training, injury type and stretching habits of Ironman triathletes should be particularly targeted at this group of health professionals.

5.8 Stretching habits of Ironman triathletes
5.8.1 Pre and post exercise stretching

Stretching prior to training was only regularly performed by 68 (23%) of the respondents. This did not seem to be associated with the number or site of injuries in these athletes. This finding is supported by Pope et al (2000) and other authors (Calder et al 1999, Chapman et al 2002, Gleim et al 1997, Herbert et al 2002). In the present study, stretching after training was more common with 130 (44%) of respondents reporting stretching always or mostly after training.

Figure 4.1 demonstrates a distinct difference in injuries between the athletes who mostly and always stretched after training, versus those who occasionally and rarely stretched after training. The unexpected finding in this graph (Figure 4.1) is the ‘never stretch after training’ respondents. These respondents may be well-suited to triathlon racing and not require stretching. A follow-up study of these athletes would be interesting to see why they did not need or choose to stretch after training. This group may have a physical characteristic that makes them less likely to get injured (Witrouw et al, 2004). This group had the lowest mean reported injuries but constituted only 21 (7%) participants in the study population.

Hartig and Henderson (1999) similarly found that military recruits who stretched after exercise experienced less injuries. They investigated all types of musculotendinous injuries, whereas the present study focussed on non-traumatic injuries. This topic warrants further investigation in the Ironman triathlete population.
5.8.2 Duration and repetition of stretches

The athletes generally seemed to hold and repeat their stretches as per the recommendations of the Australian Physiotherapy Association’s Sports Physiotherapy Australia Group (lower limb and upper limb stretching sheets, Australian Physiotherapy Association, 2010). These recommendations are to hold the stretches for 20 seconds and perform them twice. In the present study, the mean hold time was 24 seconds and the mean number of repetitions was 2.5 times. The duration and repetition of the stretches however did not appear to be related to the number or site of injuries. This finding is supported by the stretching literature (Bandy et al 1997, Hartig and Henderson, 1999, Herbert and Gabriel 2002, Pope et al 2000). These three studies all used different repetitions and durations of stretches and found that there was no statistically significant difference in injury if these two factors were changed.

5.8.3 Body areas stretched

The respondents stretched the muscles of the lower limb far more frequently than any other part of the body. Considering the knee was the most frequently injured part of the body this would appear to be appropriate. Other areas of the lower limb also featured prominently in the injured list, including the ankle/foot and the hip/butt/groin. Interestingly, the lower back was the second most injured body area and yet it was only the sixth most stretched area. This area warrants further investigation, using a prospective research design.
5.8.4 Resources respondents used to learn their stretches

Respondents reported eight different sources for their stretching information. In 33% of responses a health professional was noted as the source. A further 30% of respondents stated that they used a combination of sources comprising of health professionals, magazines and books. The third most used source was a coach (10% of respondents). If an athlete learned their stretches from a health professional, it may have been part of the treatment process for an injury.

5.9 Limitations of this study

The use of a questionnaire gives a snapshot of the triathletes, however it is not an instrument that allows us to attribute causality. The information gained is broad but should help to direct further research in this area. Although the sample appears representative of the race population, the response rate was low. Other marketing strategies may have resulted in a higher response rate. Although athletes stated whether they stretched or not, the findings cannot indicate whether stretching was used to prevent or treat injuries. While a definition of injury was included in the questionnaire, it was still somewhat open to interpretation by the athletes. The definition of injury is not yet standardised in the literature for triathletes. With the questionnaire relying on self-reporting this may introduce bias, such as recall bias. The final limitation is the Neyman bias or prevalence-incidence bias. This is where any risk factor that prevents a triathlete participating in an Ironman triathlon is under represented. A longitudinal design would help to reduce this bias.
CHAPTER 6

SUMMARY

6.1 Key research findings

The characteristics, training loads, injury patterns and stretching habits of 296 participants in the 2006 Australian Ironman Triathlon were examined in this study. The focus of this summary relates to stretching and injuries.

Some of the findings agreed with previous research on stretching. Most notably, stretching before training had no significant effect on reducing injuries (Pope et al 2000), whereas stretching after training had some effects on reducing injury (Hartig and Henderson 1999).

There was no significant association between overall training load and injuries, while the most injured sites were the knee and then the lower back. (O’Toole et al 1989).

The incidence of injury (2.38 per 1000 hours of training) was quite low when compared to other sports such as football, netball and hockey. Despite the fact that the amount of time spent training per week was 19.5 hours.

There was some benefit in being a member of a triathlon squad in reducing the amount of time having to modify training due to injury. For athletes this would suggest that training with a triathlon squad is desirable in reducing injuries.

The more time an athlete spent running the more likely they were to experience a shin injury.

Interestingly the data suggested that injured athletes spent more time stretching but this does not indicate causality.
Male and female triathletes experience a difference in the distribution of the injuries they sustain (Vleck et al 1998). Excess training was the most attributed cause for injury with physiotherapists the most consulted professionals. Professional treatment and rest were the most common injury management strategies.

Rest and physiotherapy treatment were perceived to be the most effective strategies in managing injuries. The large amount of time spent training each week (19.5 hours per week) by the athletes would suggest that overtraining might be a common cause and that relative rest may be a useful treatment. Education for physiotherapists as to the nature and demands of triathlon training and racing might be beneficial, as they are the most consulted health professional.

6.2 Further research

As Herbert and Gabriel stated in their systematic review in 2002, “the quality and statistical validity of studies of stretching is generally of a low standard.” (Herbert and Gabriel, 2002. p.471). A follow-up of athletes in this present study to determine whether they stretched to prevent or treat injuries maybe beneficial, and to further explore why of the triathletes did not stretch at all.

A prospective study with individualised stretching programs for each athlete may be the next step in examining the value of stretching in preventing and/or treating injuries as well as improving performance. This would better reflect the way stretching is used in the modern physiotherapy practice.

In the clinical setting, a clinician will prescribe stretches to a patient if the clinician thinks that this is a valid intervention. These stretches are usually customised for the athlete and
would not necessarily have a positive effect on a different athlete. Ideally non-injured athletes would be assigned to a prospective study to determine whether stretching after training has an injury prevention effect. In addition, a follow-up of athletes in this study to determine whether they stretched to prevent or treat injuries would be useful.

In this study training load did not seem to be related to injury. A more detailed examination of training including intensity, periodisation and environmental factors might establish some associations. If relative rest is a useful treatment strategy in the treatment of non-traumatic injuries then there may be an association with training, however our investigations have not been sensitive enough to find the relationship. Future studies examining training programs may be of worth.
REFERENCE LIST


APPENDICES

Appendix 1  questionnaire
Appendix 2  letter of invite
Appendix 3  ethics approval
Appendix 4  IMG approval
An investigation into the injuries sustained by ironman triathletes and the preventative effect of post-exercise stretching

Please answer the following questions by either:

- Placing a tick in the appropriate box
- Writing a response on the line

1. Age: ______ years
2. Gender:  □ Male  □ Female
3. Height: _____ cm
4. Weight: _____ kg
5. I’ve been racing in triathlons for ______ years.
6. Before triathlon, the sport I was most competitive in was _______________________
7. I currently train with a:  □ Triathlon Coach  □ Triathlon Squad
   □ Swimming Coach   □ Swimming Squad
   □ Cycling Coach   □ Cycling Squad
   □ Running Coach   □ Running Squad
8. I had my bicycle professionally fitted  □ Yes  □ No

9. I wear orthotics in my running shoes  □ Yes  □ No

10. My fastest time for the Forster ironman is:
    □ 8-10 hours  □ 10-12 hours  □ 12 hours +  □ yet to post a time

11. Over the last 12 months due to chronic or overuse injuries I was **unable to train** for
    ___________ months  __________ weeks  __________ days

12. Over the last 12 months due to chronic or overuse injuries I **modified** my training for
    ___________ months  __________ weeks  __________ days

13. My average training schedule over the last 12 months

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>_____ Hours spent swimming per week</td>
<td>_____ Hours of strength training per week</td>
</tr>
<tr>
<td>_____ Hours spent cycling per week</td>
<td>_____ Hours of stretching per week</td>
</tr>
<tr>
<td>_____ Hours spent running per week</td>
<td>_____ Hours of other sports per week</td>
</tr>
</tbody>
</table>
14. As an Ironman Triathlete have you had any long lasting injuries or chronic pain in the following areas?

Please Tick The Area(s):

<table>
<thead>
<tr>
<th>Area</th>
<th>I attributed the injuries to</th>
<th>I sought professional help from</th>
<th>The injuries improved with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head / Neck</td>
<td>- Excess training</td>
<td>- Doctor</td>
<td>- Rest,</td>
</tr>
<tr>
<td>Shoulder / Arm</td>
<td>- Poor technique</td>
<td>- Masseur</td>
<td>- Changing training,</td>
</tr>
<tr>
<td>Wrist / Hand</td>
<td>- Old shoes</td>
<td>- Physio etc.</td>
<td>- Treatment etc.</td>
</tr>
<tr>
<td>Chest / Abdomen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper back</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower back</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hips / Buttock / Groin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thigh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle / Foot</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

15. I stretch **before** I train: (a percentage of the number of your workouts)

- [ ] Always    100%
- [ ] Mostly     75%
- [ ] Occasionally 50%
- [ ] Rarely     25%
- [ ] Never      0%

16. I stretch **after** I train: (a percentage of the number of your workouts)
17. I hold each stretch for ______ seconds  
18. I repeat each stretch ______ times

19. I learnt my stretches from:

- [ ] Magazine/book  
- [ ] Coach  
- [ ] Health Professional  
- [ ] Athlete  
- [ ] Video/DVD  
- [ ] Other _______________________

20. I stretch the following parts of my body:

- [ ] Neck  
- [ ] Buttocks  
- [ ] Shoulders  
- [ ] Front of Thigh  
- [ ] Upper back  
- [ ] Back of thigh  
- [ ] Lower Back  
- [ ] Calf  
- [ ] Groin / Hip  
- [ ] Other _______________________

21. I am willing to be contacted to participate in further studies  
- [ ] Yes  
- [ ] No

Thank you for completing this questionnaire. Please return it in the enclosed envelope as soon as possible.
An investigation into the injuries sustained by ironman triathletes and the preventative effect of post-exercise stretching

Dear Participant of the Australian Ironman 2006,

As part of his Master of Medical Science (Physiotherapy) at the University of Newcastle, Warren Ansell is researching overuse injuries in ironman triathletes and their use of stretching after training and racing. This research is being conducted under the supervision of Associate Professor Darren Rivett and Dr Robin Callister. Warren is also a qualified physiotherapist and ironman triathlete himself.

We invite you to participate in this research project by completing the enclosed brief questionnaire and returning it in the enclosed stamped self-addressed envelope. The questionnaire only takes about 10 minutes to complete. By participating you are giving consent for the information to be used for research purposes and you will be contributing to our understanding of overuse injuries in ironman triathletes and the role of stretching in their prevention.

All entrants of the Forster Ironman 2005 have been selected, however your participation is confidential and entirely voluntary and you are under no obligation to complete the questionnaire. The information you provide will only be used for the purposes of the study. Ironman Australia is distributing the questionnaire to ensure that the researchers do not have access to your name or details to protect your privacy. Each form and envelope is coded to help us ensure all race participants have received a questionnaire. You will not be identified in any publication or presentation of the study findings. A summary of the results will be made available via the Ironman Australia organising committee.

At the end of the questionnaire there is an opportunity for you to agree to be contacted to participate in further research studies. These studies would involve asking you further questions about your stretching habits and possibly asking you to follow a stretching regime. Agreeing to be contacted is entirely voluntary and does not obligate you to participate.
Ironman Australia will contact you using the code on your questionnaire and will not reveal your name or contact details to the researchers.

Please return your completed questionnaire by the 30th of April 2005. By returning your questionnaire you will also go into the draw for a free entry into a half ironman race of your choice in the 2005-2006 season. You will be notified by Ironman Australia via mail if you have won the free entry. Thank you for considering this invitation.

If you have any queries about this study please contact Warren Ansell (02 67 652 333, email Warren.Ansell@studentmail.newcastle.edu.au) or Associate Professor Darren Rivett (phone 02 4921 7821, email Darren.Rivett@newcastle.edu.au).

This research project has been approved by the University of Newcastle Human Research Ethics Committee, approval No….

Should you have any concerns about your rights as a participant in this research, or if you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, telephone (02 4921 6333, email Human-Ethics@newcastle.edu.au.

Yours sincerely,

Warren Ansell (Research Higher Degree Student)
Associate Professor Darren Rivett (Principal Supervisor)
Re: An investigation into the injuries sustained by Ironman triathletes and the preventative effect of post-exercise stretching

Dear Associate Professor Rivett

Thank you for your recent application to the Human Research Ethics Committee, seeking approval for the above study, which is the higher degree research of Mr Warren Ansell. The Committee was able to consider your application at its meeting on 16 February 2005.

Following consideration of your application, the Committee agreed that approval would be granted subject to you responding to the matters detailed on the attached.

Please let me have your response in the form of a letter with one copy of amended documentation at your earliest convenience. For ease of review, please highlight amendments to the documents and include an updated version number and date. Your letter should be addressed to:

Ms Susan O'Connor
Human Research Ethics Officer
Research Office
The University of Newcastle
University Drive
Callaghan NSW 2308

Kind regards
Ruth

Ms Ruth Gibbins
Administrative Officer
Human Research Ethics
Research Office
The University of Newcastle
University Drive
CALLAGHAN NSW 2308
AUSTRALIA
Ph. +61 2 4921 7428
Fax. +61 2 4921 7164
email: Ruth.Gibbins@newcastle.edu.au
Hi Warren, I can confirm here that you have requested access to our competitor data/kit bags for the purpose of issuing a questionnaire as part of your research study at the University. We are prepared to consider this as part of our race registration process subject to a financial consideration being agreed upon.

Regards Ken Baggs
Race Director