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**THE EPIDEMIOLOGY OF INJURIES SUSTAINED BY
CANOEISTS DURING THE 2006 ISUZU BERG RIVER
CANOE MARATHON**

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M.Phil (Sports Physiotherapy) at the University of Cape Town

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Abstract

Aim: To establish the incidence of injuries sustained by canoeists during the 2006 Isuzu Berg River Canoe Marathon.

Methods: Male canoeists who qualified to compete in the race and were registered for the 2006 Isuzu Berg River Canoe Marathon were asked to volunteer for the study. Subjects were healthy volunteers aged between 18 and 65 years. Fifty-seven participants met the inclusion criteria and were included in the study. A baseline questionnaire was administered during race registration. A daily injury questionnaire was administered at the end of each stage of the 4-day event.

Results: Forty-eight of the study participants reported injuries (84.2%). Injuries were classified according to site and type. The most common sites of injury were the hands (25%), the shoulder girdle (17.1%) and the lumbar spine (11.4%). The most common types of injury were muscle strains (30%), blisters (25%) and muscle cramps (20%). Factors contributing to injury were analysed under intrinsic and extrinsic headers. The intrinsic factor of age was found to be associated with muscle strains. Canoeists who reported muscular strains were significantly younger than those who did not (33.8 yrs \pm 10.78 vs. 40.2 yrs \pm 10.76; $p = 0.03$). With regard to extrinsic factors, there was an association between weightlifting training and injury. Almost half of the participants ($n = 57$) used weightlifting training in the six months prior to this event (47.36%). Several types of weight training exercises were found to be associated with incidence of injury including; incline fly's ($p = 0.001$), chin-ups with a weight belt ($p = 0.014$), chin-ups without a weight belt ($p = 0.018$) supine fly's ($p = 0.026$) one arm rows ($p = 0.044$), and triceps dips without a weight belt ($p = 0.045$).

Conclusion: Canoeists participating in long distance multi-stage events appear to be at high risk for sustaining soft tissue injuries. Younger canoeists appear to be at particular risk for muscle strains. The use of certain weightlifting training exercises may be associated with soft tissue injury provocation.

Keywords

Canoe/Kayak injuries, Incidence, Questionnaire, Multiple day events/Marathons

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INTRODUCTION

Canoeing is a growing sport worldwide and has grown from 16.7 million participants in 1994/1995 to 22.6 million participants in 1999 (Schoen, 2002). With the 15% annual increase in participants, there has been an associated increase in injuries (Fiore et al, 2001; O'Hare et al, 2002; Schoen et al, 2002).

The Berg River Canoe Marathon is an unusually long, four-day 239 km event (du Toit et al, 1999), which has been held annually since 1969. The distances that are paddled daily in this event are almost double those of standard two-day canoe marathons such as the Sella Descent (Spain), Liffy Marathon (Ireland) and the Fish River Marathon (South Africa). Owing to the volume of training and racing required for this distance, overuse and exposure injuries cannot be ignored (Parkkari et al, 2004). However, data regarding the incidence of injuries sustained during this race have not been gathered. Other factors that make the Berg River Canoe Marathon unique include the extreme conditions in which the canoeists compete. The race is held in early July (winter), in the Paarl Valley of the Western Cape Province of South Africa. The winter weather in the region includes rain, wind, hail and extreme cold. The river is therefore prone to varying water levels. This contributes to the unpredictable topography of the river, a result of which is that the canoeists may get lost, thereby increasing their time spent on the water.

Musculoskeletal injuries are a common occurrence in endurance sports. In the limited canoeing literature available, musculoskeletal injuries are commonly reported, with injury sites typically involving the upper body (Schoen et al, 2002; Hagemann et al, 2004).

Various intrinsic and extrinsic factors have been identified as contributing to musculoskeletal injuries in the general athletic population. In endurance canoeists, intrinsic variables may include age, height, gender, and body mass (Shepard, 1987). Extrinsic factors may include training methods, weight training, (Gross et al, 1993; Gauthier, 1989) and environmental conditions; including wind, cold temperatures, water level and velocity of water flow (Rumball et al, 2005; Fiore, 2003; Shepard, 1987).

1.1 Statement of the Problem and Research Question

Endurance canoeists are potentially at risk of injury. However, little information is available regarding the incidence of injuries and factors contributing to injuries. This is particularly evident in a South African population, where the participation in multi-day endurance events is growing.

Accordingly, the purpose of this study was to explore the incidence of injuries in K1 marathon canoeists participating in the 2006 Isuzu Berg River Canoe Marathon, and to investigate the associated contributing factors to injury.

1.2 Aims and Objectives

The aim of the study was to determine the incidence of canoeing injuries in the 2006 Berg River Canoe Marathon. The specific objectives were:

- i) To determine the frequency and type of injuries sustained during the marathon;
- ii) To assess whether there was a correlation between injury type and:
 - a. Age,
 - b. Body mass,
 - c. Height,
 - d. Body Mass Index,
 - e. Training (distance per week and weightlifting training),
 - f. Number of years canoeing,
 - g. Experience in previous canoe marathons,
 - h. Equipment (boat and paddle type),
 - i. Physical trauma (capsize/ tree blocks/ immersion).

1.3 Significance of the Study

Very little research in the past has focused on paddling as a sport, leading to a lack of information on the incidence, mechanism, and contributing factors to paddling injuries. This study aims to increase knowledge regarding both the epidemiology of canoeing

injuries, as well as the predisposing factors to injury. This is essential for effective injury prevention and management, in order to reduce the incidence of injuries, as well as time off training and competition. The results of the research are intended to contribute to a decreased future injury incidence at the Isuzu Berg River Canoe Marathon. They will, therefore, be communicated to the race organizers and relevant medical support staff.

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2 LITERATURE REVIEW

A search was conducted on literature relevant to canoeing and associated topics. Using the search engines of PubMed and the Health Science Library at the University of the Witwatersrand, a search was conducted. Keywords used were: canoeing injuries, swimming injuries, rowing injuries, multiple stage events, and marathon running injuries. The review covered relevant publications from 1970 to 2008.

2.1 Epidemiology

While little is known about the epidemiology of long distance canoeists' injuries in South Africa, the international literature does present some limited information highlighting major types, sites and causes of injuries in canoeists.

The studies that were reviewed predominantly covered the same boat types as seen in this research; the K1 canoes. The boat types being used in the 2006 Isuzu Berg River Canoe Marathon were the same class canoes as those surveyed (77.7%) by Kameyama et al (1999). A review conducted by Fiore (2003) mentions 6,5 million of the same style of canoe, while in a study by Krupnick et al (1998), 75% of participants used the same class of canoe.

In a large epidemiological study involving the Japanese Canoe Association, 821 canoeists were surveyed, using a sports injury questionnaire. Of the 417 canoeists who completed the questionnaire, 94 canoeists (22.5%) reported lumbar pain, 20.9% experienced shoulder pain, 10.8% wrist pain; and 3.8% elbow pain. The study covered a variety of racing styles, including kayak (n = 324), Canadian canoe (n = 71), slalom (n = 13), and others not specified. The majority of canoeists were men (n = 306), with 103 being women, and the remaining subjects' gender not noted. A variable not recorded in the study was whether the participants were sprint or marathon canoeists. The average canoeing career duration was 7.8 ± 3.6 years (range 2-20 years). These canoeists reported training for canoeing for 4.1 ± 1.6 hours (range, 2-8 hours) every day (Kameyama et al, 1999).

Kameyama et al (1999) conducted one of the most relevant studies related to canoeing. Despite the inability of the reader to discern between racing types and canoe techniques, this study gives a valuable general impression regarding the typical injuries seen amongst canoeists. Through the thorough reporting of demographics, the impression is given that the sport of canoeing is male-dominated and participants have varied experience and training regimens.

Further, physical examinations conducted on the Japanese sample revealed that the lumbar pain reported by participants (22.5%) was mainly myofascial in origin, whereas examinations revealed shoulder pain to stem from impingement, tendinopathy osteoarthritis and clavicular deformity. Examinations also revealed osteoarthritis in some of the canoeists suffering elbow pain (Kameyama et al, 1999).

In a systematic literature review of injuries sustained by white-water canoeists, blisters on canoeists' hands are noted as the main injury, with between 30% and 90% of canoeists suffering this soft tissue injury. From the studies surveyed, it was found that injury to the upper extremity was most common, with the shoulder the most likely joint to be damaged. The types of injury varied; the most prevalent being due to soft tissue overuse and shoulder dislocations. Although this review focused on white-water canoeists and not on K1 marathon canoeists, it showed relevance to the topic, since the 6.5 million canoeists comprising the sample were recorded as using craft in the same class as those used in the 2006 Isuzu Berg River Canoe Marathon. Canoeists surveyed in these studies participated on rivers graded from I to VI, which encompassed small waves, with no serious obstacles, to extremely difficult and high-risk rivers. The review makes the assumption that each canoeing day is 8 hours long; a similar length of canoeing day to that experienced by competitors in the Isuzu Berg River Canoe Marathon. The canoeists reviewed were almost 70% male, and overwhelmingly white (over 90%). Unfortunately, because of the retrospective nature of the studies involved, it was not possible to calculate true injury rates (Fiore, 2003).

In a study surveying injuries in competitive white-water canoeists along four different river courses in the United States, 375 questionnaires were distributed and 54 were completed and returned (Krupnick et al, 1998). The authors investigated the total number of injuries sustained by canoeists. Seventy five percent of the canoeists in this study used craft in the same class as those used in the 2006 Isuzu Berg River Canoe Marathon. The majority of canoeists were male (75%), with a median age of 34 years, and 10.7 years of canoeing experience. The results of this study had to be treated with some caution as the response rate was only 14.4%, the results possibly being biased towards canoeists who did sustain injuries.

Krupnick et al (1998) was in agreement with previous surveys, reporting that spinal injuries were concentrated in the lumbar region, and that shoulder and hand injuries were the most prevalent upper extremity injuries (Kameyama et al, 1999; Fiore, 2003; Krupnick et al, 1998). In addition, 10% of participants complained of a near drowning incident in their paddling career. This finding was contrary to those of the study performed by Fiore (2003). The main types of injuries reported included sprains (32%), tendinopathies (20%), and musculoskeletal pain (14%). The authors also analysed the total number of injuries sustained in a canoeist's injury history: 56% of injuries were recorded as having occurred during training, 40% were sustained during recreation, while only 4% occurred during competition. The percentages were reported by canoeists themselves and may not be accurate, objective statistics. Of note is that although only 4% of injuries occurred during competition, the injury risk per hour of exposure was higher in competition than in training.

Krupnick et al (1998) also compared injuries sustained to time spent on the water. A more accurate indication of injury frequency is risk per hour of exposure. It is defined as the number of injuries divided by the total number of paddling hours. The injury risk during training was estimated as 0.1 injuries per hour, with an injury risk of 0.04 injuries per hour during recreational activities. This was compared with an injury risk of 1.12 injuries per hour during racing and competition. The amount of time canoeists spend on the water is greater in training than in racing. Even though more injuries in total were sustained in recreational canoeing and training, owing to the higher intensity and effort of racing, together with less time spent on the water, the risk was higher in racing.

In summary; previous studies have identified the lumbar spine and the upper extremity, specifically the hands and shoulders, as common regions that may be injured during canoeing activities. Furthermore, canoeing injuries have been reported to be primarily soft tissue in nature, and may include sprains, tendinopathy and musculoskeletal injuries (Kameyama et al, 1999; Fiore, 2003; Krupnick et al, 1998). Owing to the intense nature of canoeing competition, injuries have been reported to occur more frequently during racing than in training (Krupnick et al, 1998). These data have been collected in various international studies but no such data exist regarding South African K1 marathon canoeists.

2.2 Canoeing-Specific Injuries

Injuries in canoeing occur at various anatomical locations, each area presenting with different types of injury. The various types, areas and causes of injury commonly associated with marathon canoeing will be expanded on in this section.

2.2.1 Sites of injuries

Owing to the nature of the sport, the areas of injury are commonly found in the trunk and upper limb. The hands may be frequently injured through the almost constant interplay between the surface of the skin and the paddle shaft. This area of injury has been reported to occur in 30% to 65% of canoeists (Fiore, 2003). The shoulder is the second most commonly reported area of injury (Schoen et al, 2002; Fiore, 2003; Hagemann et al, 2004). Injuries to the face, head and neck have been reported as the third most likely to occur (Fiore, 2003; Fiore et al, 2001). The lumbar spine, wrist and elbow are also noted as being frequently injured during canoeing (Teitz et al, 2002; Fiore, 2003; du Toit et al, 1999). The lower limbs are not reported as regular marathon canoeing injury sites, but have been mentioned in literature describing cross-training and submersion trauma (Stanton et al, 2002; Krupnick et al, 1998). Different types of injuries may occur at each of these anatomical sites.

2.2.2 Types of injuries

Musculoskeletal injuries appear to comprise the majority of other canoeing injuries. Muscle strains are most frequently reported, with tendinoses also noted as a common injury type (du Toit et al, 1999; Schoen et al, 2002). Blisters are reported as the most frequent type of injury involving the canoeists' hands (Fiore, 2003). Additionally, haematomas, fractures, dislocations, and lacerations have also been described as common in canoeists (Krupnick et al, 1998). A further description of common canoeing injuries follows.

2.2.3 Non specific lower back pain

Lumbar pain due to various causes is noted as a prevalent problem amongst canoeists, with a study of 392 canoeists recording 31% complaints of lower back pain (Fiore et al, 2001). Schoen et al (2002) described back pain as an acute complaint in 13%, and a chronic complaint in 14% of 267 canoeists. Several factors have been proposed as contributing to the development of lumbar injuries in canoeists. These may include hyperflexion of the lumbar spine (Stallard, 1980), erector spinae fatigue and strength asymmetries in left and right erector spinae muscles during extension (Parkin et al, 2001), early morning training (Reid et al, 2000), breathing patterns and increased respiratory demands (Loring et al, 1982), a low hamstring to quadriceps ratio (Koutedakis et al, 1997), hip muscle imbalances, particularly in female canoeists (Morris et al, 2000), and lumbar postures and the function of core stabilisers (Rumball et al, 2005).

It has been reported that hyperflexion during the paddling stroke may facilitate the onset of lower back pain (Kameyama et al, 1999). Hyperflexion and rotational forces are aggravated during the catch position of the paddling stroke. Excessive loading of the spine occurs as the paddle blade is driven through the water. It is estimated that the compressive forces placed on the lumbar spine may be four to six times the canoeist's body mass (Morris et al, 2000). These compressive forces are compounded by fatigue, which, combined with high training volume, and intensity, may impair muscle contractibility (Karlson, 2000; Caldwell et al, 2003).

Caldwell et al (2003) suggested that fatigue of the erector spinae muscles may result in excessive lumbar flexion, thereby increasing stress on spinal structures. The effect of muscle fatigue is exacerbated by decreased awareness of excessive lumbar flexion, which occurs with muscle fatigue in long-distance events (Taimela et al, 1999). In order to prevent lower back pain, some authors recommend increasing the endurance capabilities of the lumbar extensors to help maintain healthy levels of lumbar flexion (Rumball et al, 2005). However, the effectiveness of this approach in the prevention of lower back pain has not been reported.

Training and participating in the early morning may appear to contribute to the development of a lumbar disc injury (Reid et al, 2000). It is thought that since lumbar discs absorb fluids from surrounding tissues overnight, and hence are swollen in the morning, they are then more prone to injury. The discs then presenting with greater volume exert increased pressure on the corresponding neural foramina. The increased pressure in flexion, from canoeing on swollen discs, may cause a lumbar disc injury since the posterior ligamentous barriers are stretched and allow discs to bulge and/ or prolapse (Kameyama et al, 1999). Lumbar discs are more compressed in the afternoon and are therefore thought to be more resistant to stresses later in the day (Reid et al, 2000; Urban et al, 1988; Adams et al, 1987). While the relationship between incidence of lumbar disc injury and training in the early mornings has been established, the effectiveness of training later in the day to prevent disc injuries has not been explored.

Breathing patterns have been hypothesised as facilitating either the development or the prevention of back injuries. The development of back injuries may be facilitated during times of increased respiratory demand, as the central nervous system prioritises respiratory drive over postural control functions. Moreover, it has been established that intra-abdominal pressure (IAP) increases during rowing (Maning et al, 2000). This increased pressure would, by virtue of Boyle's Law, decrease abdominal volume and thus, facilitate a reduction in the high levels of shear and compression forces that occur during sustained lumbar flexion in canoeing (Maning et al, 2000; Kameyama et al, 1999).

In rowing, it has been shown that inspiration training may improve thoracic stability, thereby decreasing lower back pain. It is further theorised that increasing the endurance and strength of the thoracic muscles results in central nervous system adaptations,

leading to decreased effects of fatigue and increased spinal postural control (Voliantis et al, 2001). While the applicability of this research to canoeing is limited, due to the differences in posture and biomechanics of rowing, it must be recognised that respiratory muscles are important, not only in controlling intrathoracic pressure but also in stabilizing the lumbar spine. Loring et al (1982) trained subjects' inspiratory muscles by breathing against a resistance equal to 50% of peak inspiratory mouth pressure, using a muscle trainer for 30 repetitions twice a day. The study showed that those subjects who had trained their inspiratory muscles experienced less back pain than those who had not. Therefore, cardiovascular training may aid performance, as well as prevent lumbar injuries (Loring et al, 1982).

It has been suggested that hip muscle imbalances, as well as imbalances in the quadriceps to hamstring ratio, increase strain on the lower back (Rumball et al, 2005). Having strong psoas muscles and adequate length in the hamstrings allows for anterior rotation of the pelvis (Caldwell et al, 2003). This increase in anterior rotation of the pelvis will reduce the amount of lumbar flexion and, therefore, decrease the stress on spinal structures involved in flexion. In addition, biomechanical analysis of the quadriceps to hamstring ratio could identify certain problems faced by canoeists with muscular imbalances. Since quadriceps and hamstrings act as antagonists, an imbalance between these would create increased strain on the lumbar spine (Rumball et al, 2005). This hypothesis regarding the role of hip muscle imbalance and hamstring to quadriceps ratio has yet to be tested.

2.2.4 Shoulder injuries

Shoulder injuries commonly reported amongst canoeists include bicipital tendinopathy, subacromial bursitis and non-specific shoulder pain (Rumball et al, 2005; Richardson et al, 1995).

Microtrauma of the rotator cuff has previously been noted in canoeing studies (Hagemann et al, 2004; Schoen et al, 2002). In a study of 52 canoeists, 52% of injuries were reported as supraspinatus musculotendinous injuries and 3.8% were reported as subscapularis injuries. In addition, marathon canoeists have been reported to be twice more likely than sprint canoeists to suffer rotator cuff pathology (Hagemann et al, 2004).

i) Paddler's shoulder

During the canoeing stroke, the enlargement of the supraspinatus musculotendinous complex, the long head of biceps tendon, or the subacromial bursa within the subacromial space, with resultant mechanical impingement and pain, has been described as "Paddler's Shoulder". It is suggested that this impingement syndrome may occur in athletes who attempt to develop or maintain effective mechanics for paddling performance (Walsh, 1985).

The mechanical irritation of the rotator cuff tendons may lead to swelling, with an associated increase in clinical signs and symptoms. In addition, associated pathomechanics, such as poor scapula control or a "beaked" acromion, may further reduce the subacromial space. The repetitive nature of the paddling stroke leads to further mechanical irritation and, as a result, degeneration of the tendons. Moreover, in older athletes, continued use together with poor healing due to impaired anatomical circulation, results in possible tearing of the rotator cuff tendons. In chronic cases, the development of bony spurs inside this anatomical space or tendon calcification may occur (Southmayd et al, 1981).

Shoulder impingement has been described as occurring as a result of rotator cuff tendons' becoming impinged whilst passing through the subacromial arch, the boundaries of which comprise the acromion, and the coracoacromial arch, together with

maintain boat speed (Pelham et al, 1995). Maximum strength development is regarded as a priority by canoeists preparing for a race. While maximum strength training may be appropriate for sprint canoeists, Pelham et al (1995) note that this is a potential training error for marathon canoeists. In the boat, contractions are never close to maximal effort, and strength training alters the biochemistry of a muscle, affecting its ability to work effectively at relatively low contractions. Specificity of training would suggest that adaptations would depend upon the type of training programme followed. It has been reported that prior to a race, after a long season of doing weights, a large number of paddlers have been recorded as presenting with shoulder injuries (Gauthier, 1989). Inappropriate dry land maximal strength training is suggested as a major extrinsic and preventable contributing factor to 'paddlers shoulder' (Pelham et al, 1995).

Paddling technique

The paddling technique is thought to be a contributing factor in the development of several injuries. Specifically, an inefficient technique may contribute towards forearm and shoulder injuries (Pelham et al, 1995; Rumball et al 2005).

It is theorised that poor paddling technique and fatigue are both underlying factors that may contribute to the development of wrist and forearm tenosynovitis, as both may result in excessive wrist motion. The canoeing stroke has components of wrist radial deviation in extension of the leading arm out of the water with the paddle horizontal to the water surface, to wrist flexion and radial deviation at the end of the stroke. It is speculated that as fatigue sets in the shoulders drop and the wrist moves less into extension just before the paddle enters the water (pre-catch), hence using less of the contractile surface of the extensor compartment of the forearm and leading to repetitive strain (Rumball et al, 2005).

In addition, an excessively tight grip may predispose to injury. It has been suggested that cold temperatures may facilitate the use of a tighter grip, which may result in wrist pathomechanics during the paddling stroke (du Toit et al, 1999).

A poor paddling technique may also contribute to shoulder injuries. The maintenance of a high top hand during the paddling stroke may result in excessive shoulder flexion and internal rotation, which is a position that facilitates the impingement of soft tissue

structures as the greater tuberosity passes under the subacromial arch (Ciullo, 1986; Nash, 1988).

Furthermore, the canoeists' level of cardiovascular fitness and skill, particularly relating to the ability to balance in an unstable canoe, are additional potential causative factors of forearm pain. The maintenance of an optimal paddling style, without repeated eccentric overload of the forearm tendons to limit hyperextension of the wrist, is important in decreasing the risk of injury. This is supported by findings that wrist and elbow pain appear to be aggravated by paddling a distance greater than 38 km. This is particularly evident during multi-stage events (du Toit et al, 1999; Rumball et al, 2005).

Training volume

A canoeist's success is dependent on paddling technique, as well as on specific muscular endurance. Therefore, an efficient paddling technique requires less muscular energy in order to maintain a specific velocity (Anderson, 1988).

This is supported by a study that reported a lower incidence of wrist tenosynovitis in canoeists who trained less than 100 km a week in the eight weeks prior to a multi-stage K1 marathon race. Possible explanations for the reduction in the incidence of injury are threefold. Firstly, training may have resulted in adaptation of forearm muscles and tendons to accommodate the load of repetitive days of canoeing. Secondly, fitter canoeists may be able to maintain the correct canoeing style for longer time periods, as it is thought that fatigue decreases concentration and hence negatively influences canoeing style. Finally, canoeists who train over 100 km a week may be a self-selected group at low risk of injury due to genetic, biomechanical or other factors (du Toit et al, 1999).

ii) Equipment

The two essential pieces of equipment involved in canoeing are the canoe and paddle. Further equipment or aides used to protect the hands are included in this section.

Canoe shape and design

Boat designs differ according to manufacturers' designs. Most boats offer a traditional diamond-shaped hull or a narrower version known as a 'slimline' model. Anecdotal

reports suggest that the extra width and flatter angle of the hull found in the original, wider diamond-shaped boats provides extra 'secondary stability' in the river. In the river, this applies to the movement of the boat caused by water or rocks, or to the way in which the boat normally rolls under the natural twist of the paddle stroke. It appears that the wider traditional shape helps to stabilize the boat as it rolls off the vertical. The slimline-shaped boat doesn't have this advantage and once the boat starts rolling it will continue in the same direction. Thus, the perception in the paddling community is that in virtually every case the slimline boat is less stable than its parent boat. The information is anecdotal and found in canoeing magazines with no reference in published journals (Macleod, 2006).

However, a previous study reported a higher incidence of tenosynovitis in K1 stable canoes, and not in the "slimline" craft. A possible explanation for this paradoxical finding is that less-experienced canoeists with poor inherent balance will select stable canoes. Thus, the injury may be related to the skill level of the canoeist, rather than to the canoe type (du Toit et al, 1999).

It has also been proposed that the seating position in a boat may be associated with the development of wrist injuries (Rumball et al, 2005). However, the influence of seating positions has not been adequately explored.

Paddle type

There is little evidence to support the role of the paddle type and length in the development of canoeing injuries. In rowing, injuries may often be related to the angle of the shaft to the blade (Tietz et al, 2002). Anecdotally, this angle is reported to be standard in most canoeing shafts. Moreover, an incorrect grip size may contribute to excessive wrist flexion and radial deviation, which may result in a repetitive strain injury. Specifically, it is theorised that the repetitive motion leads to inflammation of the tenosynovium together with hypertrophy of the extensor pollicis brevis and abductor pollicis longus tendons, with resultant forearm swelling (Rumball et al, 2005). However, a previous study reported that the paddle angle and canoe stability did not significantly influence the development of wrist injuries during a multi-stage K1 marathon race (du Toit et al, 1999).

Hand protection

The most common acute canoeing injuries are blisters, with 30% to 65% of participants suffering from this complaint (Fiore, 2003). Blisters occur through excessive friction between the skin and the paddle shaft (Schoen et al, 2002). Anecdotally, canoeists commonly use dubbin (a leather sealant) and vaseline to help prevent blisters. Changing equipment, increased humidity and increased intensity of paddling are reported to contribute to blisters in rowing (Redgrave, 1992). However, little information is available regarding causative factors and the role of hand protection in the prevention of blisters in canoeists.

iii) Environmental factors

Difficult paddling conditions, uneven surfaces, strong winds, cold ambient temperatures and fast-flowing water may all cause a change in paddling styles, which may increase the risk of injury (du Toit et al, 1999; Krupnick et al, 1998).

Water levels

Schoen et al (2002) reported that the flow rate and gradient of rivers influence injuries. Fast-flowing water has been suggested as leading to improper use of the wrist in the canoe stroke (Rumball et al, 2005; du Toit et al, 1999). It is proposed that the dominant hand is the more likely one to develop tenosynovitis, owing to the eccentric overload involved in limiting wrist hyperextension, particularly if the non-dominant hand grips the paddle too tightly, resulting in an insufficient rotation of the paddle blade. du Toit et al (1999) suggested that rough water conditions force canoeists to grip the paddle with the non-dominant hand in order to maintain balance, thereby predisposing the canoeist to tenosynovitis. This theory appears to be supported by Fiore (2003), reporting that the higher the gradient of the river and thus, the greater the river velocity and turbulence, the more serious the injury. It is suggested that these factors make the boat unstable in the water, forcing the canoeist to use the paddle for balance rather than for propulsion. Bracing to avoid capsizing involves higher torque muscular contractions than those involved in regular canoeing; resulting in injury (Fiore et al, 2001; Fiore, 2003).

Temperatures

Cold temperatures may lead to a tighter grip, which may limit the correct use of the wrist for controlling the paddle shaft and cause wrist and forearm tenosynovitis (du Toit et al, 1999; Rumball et al, 2005). Gripping the shaft too tightly limits the wrists' range of motion

and the normal contractibility of the forearm muscles. Cold temperatures may, furthermore, influence the digits of the hand, resulting in higher grip forces due to reduced sensory feedback (Nowak et al, 2003).

Hypothermia due to immersion in cold water has previously been reported as accounting for few injuries in canoeing (Fiore, 2003). However, should immersion in cold conditions occur, several medical problems, including frontal headache, anxiety, difficulty in talking, temperospatial disorientation, swelling of the hands, loss of consciousness, bronchospasm/hyperventilation, and atrial fibrillation or cardiac arrest, may ensue (Shepherd, 1987; Fiore, 2003).

Wind

High winds have been found to alter paddling styles and may lead to wrist and forearm tenosynovitis (du Toit et al, 1999; Rumball et al, 2005). Increased wind velocity may require a firmer grip on the paddle shaft, with subsequent overload and potential damage to structures, as described above. Furthermore, strong winds may decrease the stability of the boat in the water and this, as in paddling in rough water, may result in additional overload of structures. In addition, du Toit et al (1999) reported a strong association between the incidence of wrist tenosynovitis and windy environmental conditions.

2.3.2 Intrinsic factors

Intrinsic variables include canoeists' height, body mass, and biomechanics at the joints involved in the canoe stroke.

i) Height and body mass

Sprint canoeists who had faster times were found to be of above average height and relatively light, with increased lean muscle mass. That winners in most classes of Olympic competitions were 2 to 8cm taller than less successful competitors was documented. Lighter canoeists were likely to have a greater power-to-weight ratio than their heavier counterparts. Taller canoeists would have longer limbs, allowing a higher pivot point and hence, a longer reach in their stroke (Shepard, 1987). While the influence

of height and body mass of sprint canoeists has been recorded, the influence on marathon performance has not been explored.

ii) **Biomechanics**

Owing to the extent to which the torso and upper limbs are used in canoeing, the biomechanics involved in the canoe stroke are discussed, with particular reference to the lumbar, shoulder, wrist and elbow regions.

Kameyama et al (1999) relate the cause of many of these injuries to the motion of paddling, theorising that the way in which canoeists propel themselves through the water concentrates physical stress onto particular parts of the body. This results in overuse injuries, particularly in the shoulder and lumbar spine. During sustained canoeing, attenuation occurs in the soft tissue restraints of the shoulder, which allows anterior glenohumeral subluxation. Prolonged strenuous activity may lead to fatigue, which, in turn, causes hyperactivity of the rotator cuff as a compensation mechanism. In time, this compensation may fail, allowing anterior subluxation, creating rotator cuff tendonitis and impingement. A hypothesis is that the lower backs of canoeists are exposed to heavy shear loads, leading to specific osteophyte formations and ballooning discs.

iii) **Canoe stroke biomechanics**

The canoe stroke requires the canoeist to sit on a fixed seat, with knees almost extended and hips in a flexed position. The ankles and feet remain in a relatively neutral position, resting on the foot bar, which controls the steering. The general spinal movement is one of flexion, lateral flexion and rotation to extension with contralateral - lateral flexion and rotation. The hand holding the paddle about to enter the water at the catch is called the 'leading arm' or 'attacking arm'. The paddle enters the water ahead of the canoeist and pulls through until it is in line with the waist, whereupon the paddle exits the water, moving through the recovery phase. The contralateral arm begins its stroke as the other arm begins the recovery phase (Kameyama et al, 1999).

In canoeing, the canoeist catches the water with the paddle blade and develops a propulsive force on the stretcher board, which in this case is the canoe interfacing with the water, propelling the boat against the water. Between the fulcrum and the functional force point of the stretcher board, many joints are connected in series and they

contribute to developing and transmitting the propulsive force. This propulsive force is produced through trunk rotation, and shoulder extension (Kameyama et al, 1999).

iv) Lumbar biomechanics

Lower back pain is frequently reported by canoeists (Fiore et al 2001, Schoen et al, 2002). Since paddling involves a sequence of repetitive movements forming a fulcrum at the lumbar spine, with the canoeist maintaining a similar repetitive position in a small canoe during a powerful paddling movement, the back will be exposed to heavy shear loads (Dalton, 1992; Sperry, 1994).

The correct canoe stroke involves maximal spinal rotation with good lumbopelvic posture. As the stroke rate is increased, lumbopelvic rotation changes markedly. Anterior lumbopelvic rotation (anterior pelvic tilt) of the hemipelvis on the side of the catch reduces significantly with increased stroke rate. In addition, the higher stroke rate, together with the combined lower limb and spinal movement during the paddling stroke, places a unilateral weight-bearing stress on the sacro-iliac ligaments. Posterior lumbopelvic rotation occurs on the side of the stroke where the paddle blade is about to exit the water (Shepherd, 1987). There is a tendency for posterior lumbopelvic rotation to increase at higher stroke rates (McGregor et al, 2004). In addition, the increased lumbar flexion and rotation increases the stress placed on the lumbar discs (Kameyama et al, 1999).

Further, lumbothoracic flexion decreases as lumbopelvic rotation decreases at the catch. Lumbothoracic extension does not change significantly in the finished position of the stroke. The implication is that the biomechanics of flexion and rotation significantly alter the mechanics of the lumbar spine (McGregor et al, 2004). Rotational and flexion torques are known to increase strain on lumbar intervertebral discs (Teitz et al, 2002). The evidence remains speculative, since finding an arthrokinematic model to measure these variables objectively on the water has proved difficult.

v) Shoulder biomechanics

It is suggested the stress generated during the initial contact between the paddle and the water may be concentrated at the shoulder, and then shifts to the elbow and spine during the stroke phase. Since the motion of paddling concentrates stress on particular

parts of the body, overuse injuries may result (Kameyama et al, 1999). Once again, the evidence regarding the role of biomechanics as a contributory factor in shoulder injuries is speculative. In order to further explain this theory, the abnormal biomechanics of the shoulder joint during the paddling stroke have been explored.

Abnormal shoulder biomechanics:

Abnormal biomechanics, resulting from force couple imbalances, excessive internal rotation with adduction, decreased acromiohumeral distance, poor scapular control and a tight posterior capsule during, and as a result of canoeing, are all variables that may predispose the canoeist to shoulder injuries. Range of movement, particularly internal rotation, is often decreased with posterior capsule tightness (Brukner and Khan, 2001). Pelham et al (1995) indicated that posterior capsule tightness is typical in canoeists with shoulder injuries.

As a result of the dominant glenohumeral joint internal rotation and adduction that occurs during the pull-through phase, subsequent imbalances between the glenohumeral internal and external rotators may develop. This may contribute to hypovascularity of the supraspinatus muscle-tendon complex (Brukner and Khan, 2001; Pelham et al, 1995). If muscular imbalances have caused significant tendon pathology, it presents with a painful arc caused by soft tissue structure impingement between these ranges (Flatlow et al, 1994).

Poor scapular control or stabilization may lead to inappropriate lateral rotation of the scapula, which may result in excessive antero-superior translation of the humeral head and impingement of soft tissue structures between the humeral head and the under-surface of the acromion (Poppen et al, 1976; Bressel et al, 2001). Additionally, tight posterior capsular structures cause antero-superior translation of the humeral head during flexion and internal rotation. This leads to narrowing of the subacromial space and increases the contact of the supraspinatus tendon on the under-surface of the acromion (Flatlow et al, 1994).

With regard to the repetitive stroke action of canoeing; any excessive or inappropriate antero-superior translation of the humeral head may result in repeated microtrauma of

the supraspinatus tendon (Pelham et al, 1995). It is therefore evident that numerous pathophysiological changes may occur during canoeing.

vi) **Elbow and wrist biomechanics**

As mentioned previously, the wrist and elbow joint are common areas of injury in long distance canoeists (du Toit et al, 1999). Both joints may potentially be involved, owing to the long flexor and extensor attachments. The grip of the dominant hand guides the angle at which the paddle blade moves both through the water and out of it. Most of the power in canoeing comes from the opposite hand, pushing the boat past the blade in the water. The hand on the side of the blade in the water acts as a guide ensuring that the blade travels perpendicularly to the canoe. Important to the technique is that the wrist of the pushing arm should not be extended during the whole pushing phase of the stroke and only in the end, prior to the catch (du Toit et al, 1999).

The canoeing stroke involves combined wrist radial deviation and extension, when the paddle is almost horizontal to the water at the catch, and combined wrist ulnar deviation and flexion, as the paddle moves through the water back to the starting position. Fatigue during canoeing allows for less glenohumeral joint flexion during the canoe stroke. The arms are then not lifted as high above the water (Pelham et al, 1995; Rumball et al, 2005). As fatigue influences the shoulders, the height of the hands above the water decreases, thereby limiting the available range of wrist extension before the catch position (Rumball et al, 2005). When the shaft is swivelled through the 90° rotation that occurs twice for each paddle stroke, the dominant hand grips the paddle while the other hand allows the shaft to rotate (du Toit et al, 1999). The hands are held almost constantly in a concentric flexor grip, with eccentric extensor action controlling the swivel action of the paddle. Several authors hypothesise that altered biomechanics of the forearm and wrist will contribute to injuries of the wrist and forearm (Pelham et al, 1995; du Toit et al, 1999; Rumball et al, 2005). There is, however, a lack of evidence regarding the role of biomechanics in these injuries.

2.4 Research Setting

The Berg River Canoe Marathon is the longest canoe race in South Africa. The race extends over four days and covers 220 kilometres from Paarl to Velddrift in the Cape Province, South Africa. Approximately 250 canoeists attempt the race each year (www.southafrica.info). The competitors are predominantly male, with a small number of female canoeists entering the race each year.

Environmental conditions during the Berg River Canoe Marathon include mid-winter weather with associated water level fluctuations, forests, narrow channels, man-made obstacles, and variable water currents. Paddlers are required to have a high level of paddling proficiency to qualify for the race (www.menshealth.co.za).

2.5 Measurement Instrument

The measurement instrument used in this study was a questionnaire. Previous canoeing studies (Kameyama et al, 1999; Krupnick et al, 1998; Hagemann et al, 2004) utilized questionnaires so that investigators could obtain large volumes of information from numerous participants.

The questionnaire used in this study was adapted from a previously validated one described by Augustyn et al (2005) and Micklesfield (2005) (Appendix 2). Augustyn et al (2005) determined that the baseline questionnaire had good inter- and intra-tester reliability. Micklesfield (2005) established that the instrument had good face and content validity which made it particularly useful for interviewing endurance athletes. Thus an adapted version was chosen for this research, as the Berg River Canoe Marathon is an endurance event.

2.6 Conclusion

The occurrence of injuries appears to be common in canoeists, and these are generally related to the multi-faceted articulations that are required. Furthermore, the repetitive nature of marathon canoeing, in particular, appears to increase the risk of overuse injuries. Intrinsic and extrinsic factors may both predispose the canoeist to injury. As no data regarding the prevalence of injuries in marathon canoeing in South Africa are available, this study aimed to investigate the prevalence of injuries and the factors contributing to injury at the 2006 Isuzu Berg River Canoe Marathon.

University of Cape Town

3 METHODOLOGY

A cross-sectional correlational quantitative survey of canoeists participating in the 2006 Isuzu Berg River Canoe marathon was conducted.

3.1 Subjects

Male participants in the 2006 Isuzu Berg River Canoe Marathon were approached for volunteer participation in the survey. Methods of recruitment are described under the section on procedure.

3.1.1 Inclusion criteria

All male canoeists who qualified to compete in the race and were registered for the 2006 Isuzu Berg River Canoe Marathon were requested to volunteer for the study. Subjects were healthy male volunteers between 18 and 65 years of age.

3.1.2 Exclusion criteria

The exclusion criteria for this study included the following:

- Any use of analgesics or anti-inflammatory drugs seven days prior to the event;
- Reported symptoms of "flu" seven days prior to the event;
- Failure to complete the event due to equipment failure;
- Reported injury sustained during the three months prior to the marathon;

3.1.3 Informed consent

Before inclusion in the study all participants were provided with an information sheet and consent form (Appendix 1). Prior to the commencement of testing, the purpose of the study, all associated risks and benefits and the right to withdraw from participation at any

time were explained. The participants were required to give written informed consent before completing the survey.

3.2 Measurement Instruments

A baseline questionnaire was adapted from a previously validated questionnaire described by Augustyn et al (2005) and Micklesfield (2005) (Appendix 2). Adaptation for this research involved exclusion of a single section, which was aimed at collecting data from female subjects regarding risk factors for osteoporosis. Augustyn et al (2005) previously determined that the baseline questionnaire had good inter- and intra-tester reliability. Micklesfield (2005) established that the instrument had good face and content validity.

The problem with using a questionnaire is that it may introduce subjective bias, however due to the nature of this broad based epidemiological study, it was the ideal instrument to obtain the varied types of information necessary. The use of pain callipers could have been used to add an objective measurement to the study, however this study's focus was not on pain and the participants may not all have participated in an additional pain survey. Clinical Tests and scanning by magnetic resonance imaging (MRI) were used in previous studies to obtain objective measurements to soft tissue injuries in canoeing (Hagemann et al, 2004). The current study investigated many variables and adding clinical tests would have meant losing some participants as they came off the water due to the time constraints between participants and investigators.

The questionnaire was administered to determine demographic information, previous medical and surgical history, training and competition history, injury history, type of equipment and physical activity levels and included preparation for the 2006 Isuzu Berg River Canoe Marathon.

An additional daily injury questionnaire (Appendix 3) was administered at the end of each day of the four-day multistage canoe marathon, to elicit injury information pertaining to injury type, site, and cause. Good inter- and intra-tester reliability was established by a previous study (Augustyn et al, 2005).

The daily injury questionnaire comprised two sections. Section One recorded the canoeist's personal details, to ensure that all data collected over the four days remained consistent. Section Two covered detailed injury history, including site, area, and type of injury. Additional information regarding environmental factors and hazards, and equipment use that may have predisposed the person to injury was also recorded.

3.3 Procedure

Ethical approval was obtained from the University of Cape Town Ethics Committee prior to conducting the research. Permission to conduct the research was obtained by the organisers of the 2006 Isuzu Berg River Canoe Marathon. The study was advertised through pamphlets, posters and electronic resources. Participants were also recruited during race registration and at the end of each stage of the four-day event. Prior to taking part in the survey, all participants were required to complete a written informed consent form (Appendix 1). Furthermore, during race registration, the baseline questionnaire (Appendix 2) was administered to determine demographic information, previous medical and surgical history, training and competition history, injury history, type of equipment and physical activity levels including preparation for the 2006 Isuzu Berg River Canoe Marathon. This self-administered questionnaire was completed at registration (before the start of the race), or when the subject was presented with an injury at the finish of each race day, if the participant had not previously completed the baseline questionnaire.

The daily injury questionnaire (Appendix 3) was administered at the end of each stage of the four-day event. Canoeists were interviewed regarding injury occurrence as they left the water at the end of each stage. After each day of racing, from 12th to the 15th of July 2006, four physiotherapy students and one physiotherapist conducted face-to-face interviews with canoeists as they came off the water. To avoid bias, the interviewers were randomly assigned to canoeists exiting the water.

This study was conducted concurrently with several other studies investigating different aspects of endurance canoeing. Consequently, the measurement instruments

presented in Appendix 2 and Appendix 3 are composite instruments and contained sections not used in this study.

3.4 Statistical Analysis

Statistical analysis was performed, using Statistica software (StatSoft, Inc. 2004 STATISTICA (data analysis software system, version 7, www.statsoft.com). Descriptive statistics were used to present the demographic features of the subject group and the frequency of the types of injuries experienced by the canoeists.

Chi-squared tests were used to examine relationships between injuries and medical conditions, previous surgery and warming up. The injuries were grouped into four types, blisters, muscle strains, muscle cramps and tendon injury to facilitate analysis. t-tests were used to examine whether there was a significant difference in height, age, mass, paddle length, boat position, training hours and days per week, number of years canoeing, number of races completed between those who sustained an injury and those who did not. In all case the level of statistical significance was set at $p < 0.05$.

3.5 Ethical Considerations

This research project was granted ethical approval by the Ethics and Research Committee of the Faculty of Health Sciences, University of Cape Town (Ethics reference number 173/2006). Marathon organizers were approached and asked to sign a letter of consent granting permission for the study to be conducted (Appendix 4). Every canoeist participating in the survey was given an information sheet and consent form (Appendix 1), in which they were informed about the purpose of the study and assured that all the information gathered would remain confidential and be used for research purposes only. Questionnaires were completed anonymously and coded according to unique boat number only. Canoeists were advised that if they wished to withdraw from the survey at any time, they were free to do so without risk or prejudice.

3.5.1 Risks

Answering the questionnaire involved no potential risks, nor were any risks associated with the measurement of body mass and height. Participation in any canoe marathon has inherent risks associated with participation in an endurance event and in a water-sport. However, the study itself posed no additional risk.

3.5.2 Benefits

This research aimed to improve the understanding of the epidemiology of canoeing injuries at the Isuzu Berg River Canoe Marathon and explore links as to the causes and future management of those injuries. On completion of the study, subjects were provided with a list of injuries that occurred during the event and information regarding possible predisposing factors. Medical teams and organizers will hopefully benefit from this study, as the survey highlighted common injuries that occurred during the event. The results of the research are intended to contribute to promotion of safer practice and provide training advice, consequently leading to decreased future injury incidence at the Isuzu Berg River Canoe Marathon. They will, therefore, be communicated to the race organizers and relevant medical support staff.

3.5.3 Confidentiality

All information obtained from the questionnaires remains confidential, as do all records and results from this study. All participants will remain anonymous in any ensuing publication.

4 RESULTS

As the purpose of the study was to investigate incidence of injury and the impact of intrinsic and extrinsic factors on injury, the results are presented in an order which reflects this. Demographic and intrinsic characteristics such as age and body mass index (BMI) are presented first. A description of extrinsic factors related to canoeing, such as training, equipment and performance, follows. It is noted that analysis of training encompasses number of years canoeing, hours per week canoeing, previous canoe marathons completed and cross training with weightlifting exercises. Environmental factors encountered during the race are also described. These cover capsizing, tree blocks, river velocity and level and obstruction caused by rocks. The third section deals with the injuries sustained and, in the final section, the relationships between injury and relevant factors are analysed.

4.1 Descriptive Characteristics

There were a total of 144 participants [male participants ($n = 137$); female participants ($n = 7$)] in the 2006 Isuzu Berg River Canoe Marathon. Seventy-five canoeists volunteered for the survey. Fifteen canoeists were subsequently excluded on the basis of either incomplete information ($n = 12$) or because they had sustained an injury less than three months before the race ($n = 3$). Only three female canoeists participated in this study. As the number of females was too small to make any statistical inferences, these participants were excluded. The demographic characteristics of the remaining 57 canoeists (41.61% of the total male participants) who participated in the study are listed in Table 4.1.

Table 4.1: Age, height, weight and BMI of participants (n = 57)

	Mean	Minimum	Maximum	Standard Deviation
Age (years)	36.8	18.0	62.0	11.1
Weight (kg)	84.3	62.0	127.0	11.1
Height (cm)	181.6	156.0	198.0	7.8
Body mass index	25.6	20.2	34.6	3.3

Table 4.2 shows that asthma, high blood pressure and bilharzia were the most common pre-existing medical conditions reported, although the majority of participants (71%) reported no pre-existing medical conditions. In contrast, 35 participants (52.2%) reported previous surgical interventions. Table 4.3 describes the areas in which previous surgical interventions were reported.

Table 4.2: Medical conditions. (Note some participants had more than one condition) (n = 57)

Condition	Count	Percent
Asthma	6	10.2%
High blood pressure	4	6.8%
Bilharzia	4	6.8%
Liver/gallbladder	1	1.7%
Other	2	3.4%
No condition	42	71.2%
Total	59	100.0%

Table 4.3: Previous surgical interventions. (Note that some participants had undergone more than one surgical intervention) (n = 57)

Surgery	Count	Percent
Lumbar	8	11.9%
Lower limb	7	10.4%
Wrist	6	9.0%
Elbow	3	4.5%
Shoulder	3	4.5%
Cervical	1	1.5%
Other	7	10.4%
None	32	47.8%
Total	67	100.0%

4.2 Injuries Sustained

Nine of the survey participants (15.79%) did not sustain any injury during the race. Forty-eight participants sustained one or more injuries during the race. The 48 participants who were injured reported a total of 140 injuries and Table 4.4 reflects the number of new daily injuries sustained by participants over the 4-day marathon.

Table 4.4: Number, by day, of new injuries sustained by paddlers over the four-day marathon. (n = 48)

Number of injuries	Day 1	Day 2	Day 3	Day 4	Total
n = 1	13	17	14	13	57
n = 2	9	9	5	3	26
n = 3	2	1	2	0	5
n = 4	4	0	0	0	4
Total	53	38	30	19	140

Day 1 showed the highest number of new injuries (n = 53), with a progressive decline in injury reporting over day 2 (n = 38), day 3 (n = 30) and day 4 (n = 19).

The most frequently injured areas were the hands (25.0%), shoulder girdle (17.1%) and the lumbar spine (11.4%). A high number of elbow and forearm injuries were also reported on Day 1 (7.9%).

4.3 Extrinsic Characteristics

4.3.1 Pre-race training and previous racing

Pre-race preparation included years of participation in canoeing and canoeing events, as well as training specifically for this event, which included canoeing and weight training. Participation in other sports is not analysed here as it falls beyond the scope of the study.

Table 4.7 summarises the extrinsic factors relating to hours spent training, years of participation in canoeing and total number of races completed. Amongst the participants there was a large range between the maximum and minimum hours spent canoeing during an ordinary training week (1-15 hours). The range of years spent canoeing was also large (1-44 years), with the mean number of years spent canoeing being almost ten years.

Table 4.7: Pre-race preparation comprising hours per week canoe training, number of years spent canoeing and total number of canoe races completed
(n = 57)

	Valid N	Mean	Minimum	Maximum	Standard Deviation
Hours per week canoe training (hours)	55	6.3	1.0	15.0	3.3
Years canoeing (years)	54	9.9	1.0	44.0	9.1
Total races	57	19.3	0.0	88.0	20.7

5 DISCUSSION

Sports injury epidemiology has been identified as a valuable asset to sports where participation is growing rapidly and where the quantity of previous literature is limited (Krupnick et al, 1998). The current study indicated the types and sites of canoeing-related injuries, together with possible intrinsic and extrinsic contributing factors.

5.1 Injuries Sustained

The main types of injury that were found in this study were: muscle strains (30%), blisters (25%), muscle cramps (20%) and tendon injuries (10%). These results are similar to those reported in previous studies, where blisters on the hands occurred in 30% to 65% of canoeists (Fiore, 2003). Although the current study covered a multi-day marathon race, the incidence of blisters was not higher than that in the single day, short duration event covered by Fiore (2003).

Furthermore, the finding that muscle strains were a leading type of injury was in agreement with findings of previous studies (Schoen et al, 2002; Hagemann et al, 2004). Hagemann et al (2004) investigated 52 canoeists and detected a two-fold greater incidence of shoulder muscle strains in marathon canoeists than in sprint canoeists. Schoen et al (2002) reported muscle strains in 26% of canoeists studied. In the current study, 30% of the injuries were muscle strains. It is thought that canoeists most commonly complain of pain that is myofascial in origin and due to the repetitive nature of trunk and upper limb movements during the canoeing stroke (Kameyama et al, 1999).

In the current study the highest incidence of muscle cramps was reported on Day 1, with a significant decrease in cramping incidence thereafter. This was unexpected, as the proposed mechanism of exercise-associated muscle cramps (EAMC) would tend to support an increase in the incidence of cramping during a multi-day endurance event (Schwellnus et al, 2008; Bentley, 1996).

Several proposed theories related to the mechanisms of EAMC include low potassium or low sodium levels, inadequate carbohydrate intake, dehydration and tight muscles. The most recent suggestion regarding the mechanism of EAMC points to the disturbance of various levels of the central and peripheral nervous systems as well as skeletal muscle (Schwellnus et al, 2008). Schwellnus et al (2008) suggest that exercise-associated muscle cramps (EAMC) are due to alterations in spinal neural reflex activity, activated by fatigue in susceptible individuals. The novel hypothesis presented by Schwellnus et al (2008) implicates several physiological mechanisms. It states that there is decreased sensory feedback by Golgi Tendon Organs and type 1b muscle spindles. In addition there is an opposing increased stimulatory input from alpha motor neurons to type 1a and II muscle spindles. The imbalance between these mechanisms predisposes the tendency for the muscle to contract. Importantly, it is the muscles in shortened positions which are more likely to experience EAMC. It is proposed that specifically, endurance athletes experience a high lifetime prevalence of EAMC, potentially due to the repetitive nature of endurance sports (Schwellnus et al, 2008).

The balanced interaction between muscle spindle activity and Golgi tendon organ function are important in the regulation of posture, muscle tone, and muscle length. It may be theorised that various intrinsic and extrinsic factors associated with marathon canoeing may result in disturbances of these receptors, potentially leading to increased motor unit recruitment and motor neuron activity and thereby, to EAMC. Therefore, the underlying mechanisms for the paradoxical finding of a reduced incidence of exercise-associated muscle cramps in the current study are unclear. Further studies are required to determine potential mechanisms and contributing factors to the development of EAMC in marathon canoeists (Schwellnus et al, 2008; Bentley, 1996).

Krupnick et al (1998) reported that 20% of the canoeists in their study suffered a tendon injury. However, in the current study, a much smaller incidence of tendon injuries (10%) was reported. Kameyama et al (1999) theorised that tendon injury may be related to fatigue and soft tissue failure following the accumulation of years of canoeing training, as well as the number of hours per day spent canoeing training. However, in the current study no relationships were found between the incidence of muscle or tendon injuries and number of hours per week of canoeing training or number of years of canoeing participation. The results may differ for several reasons. In the current study, only 14

tendon injuries were reported throughout the race. Not all of the race participants were included in the study. In addition, classification of injury was based on self-reporting and objective assessment was not conducted. These methodological weaknesses may have resulted in under-reporting of tendon injuries. However, it is likely that training adaptations are possible among canoeists (du Toit et al, 1999). In particular, the preparatory training required for participation in this canoe marathon may be associated with positive adaptations leading to a reduction in the incidence of tendon injuries. Exercise-induced adaptations may be seen at the muscle and tendon level. An increase in the number of sarcomeres distributed in series has been observed following intensive periods of eccentric training, and has been suggested to have a protective effect on the muscle-tendon structure (Pull et al, 2007). Owing to the limited number of canoeing-related studies, arthrokinematic models and specific research aimed at tendon adaptations in canoeists, further specific research may be necessary.

Furthermore, long-term eccentric endurance training may provide a protective adaptation against injury (Lynch et al, 1997). Lynch et al (1997) proposed that this protective adaptation may be related to the relative increase in the proportion of slow-twitch fibres associated with repetitive endurance training. It is thought that slow-twitch fibres may be less susceptible to injury than fast-twitch fibres. It may therefore be theorised that endurance-trained canoeists participating in the 4-day Berg River Canoe Marathon, who will have more slow-twitch fibres, may be a pre-selected group with a decreased risk of developing tendon injuries (Lynch et al, 1997; Gonzalez et al, 2006). This theory is supported by du Toit et al (1999), who found a reduction in the incidence of forearm tenosynovitis in fitter canoeists and suggested that fitter canoeists are able to maintain optimal canoeing technique, thereby reducing the risk of injury (du Toit et al, 1999).

The main areas of injury, in this study, included the hands, shoulders, and the lumbar spine. These findings concur favourably with previous studies (Fiore, 2003; Krupnick et al, 1998; Kameyama et al, 1999).

In this investigation, 17.1% of the participants reported shoulder girdle injuries. Similarly, Krupnick et al (1998) reported a 20% incidence of shoulder injuries and Kameyama et al (1999) reported a 21% incidence of shoulder injuries in canoeists. Shoulder injuries are theorised to occur in canoeing because of the repetitive action of the shoulder joint,

leading to possible microtrauma of the rotator cuff tendons (Neer, 1983; Southmayd et al, 1981). It has been hypothesized that during repetitive canoeing strokes, there may be enlargement of the supraspinatus muscle or tendon, the long head of biceps, or the subacromial bursa within the subacromial space. This may result in a mechanical impingement described as "paddlers shoulder" (Pelham et al, 1995).

Lumbar spine injuries may occur frequently amongst canoeists, owing to the sequence of repetitive movements that occur around the fulcrum of the lumbar spine (Fiore et al, 2001). Fiore et al (2001) reported a 31% incidence of lumbar injuries, a higher figure than the 11.4% incidence of lumbar injuries in the current study. The higher incidence reported by Fiore et al (2001) may possibly be due to the inclusion of whitewater canoeists in the sample. The intensity of whitewater canoeing may be much higher than that experienced in marathon canoeing. The development of a model to determine lumbar arthrokinematics during canoeing is required, in order to improve understanding of the factors contributing to lumbar injury in this sport.

Wrist and elbow injuries have previously been reported as common areas of injury in long-distance canoeists. An average incidence of 23% has been reported in South African canoeists (du Toit et al, 1999). The current study established a 7.9% incidence of elbow and forearm injuries, and a 6.4% incidence of wrist injuries. It has been suggested that the repetitive nature of elbow and wrist flexion and extension, combined with an almost constant concentric flexor grip during the canoeing stroke, may contribute to the development of elbow, forearm and wrist injuries (du Toit et al, 1999). The reported injury incidence difference between this study and that of du Toit et al (1999) may be related to differences between the studies in subject selection. The current study investigated the general incidence of injury during each stage of the Berg River Canoe Marathon.

In contrast, du Toit et al (1999) determined the incidence of forearm tenosynovitis in the race finishers of four events: the Berg River Canoe Marathon, the Breede River Canoe Marathon, the Port Elizabeth to East London Surfski Marathon, and the Dusi River Canoe Marathon. It is recognised that the conditions during these races are extremely variable. The Dusi River Canoe Marathon involves more white water canoeing and portaging over great distances than the Berg River Marathon does. The Port Elizabeth to

East London Surfski Marathon is held in the ocean, where the extrinsic variables differ with regard to equipment and conditions. The Berg River has significant stretches of flat water interspersed with occasional rapids, and therefore requires less bracing in order to maintain stability. The grip on the paddle may be more relaxed and may, thus, contribute to a reduction in the incidence of elbow, forearm and wrist injuries among participants of the Berg River Canoe Marathon (du Toit et al, 1999).

5.2 Factors Contributing to Injury

The limited literature regarding canoeing injuries suggests that intrinsic characteristics, sports-specific training durations, overall positions in a race, and paddle lengths may be factors contributing to the development of injury (Kameyama et al, 1999; du Toit et al, 1999; Teitz et al, 2002). Thus, in this research, relationships between the four main types of injuries and the previously mentioned factors were explored.

In this study a significant relationship was found between age and the incidence of muscle strains, with younger canoeists reporting a higher incidence of muscle strains. Previous studies have not identified age as a contributing factor in the development of muscle strains (Schoen et al, 2002; Hagemann et al, 2004). The increased incidence of injury in younger canoeists was an unexpected finding, considering the well-documented age-related changes in muscle histology. Decreased muscle size and strength is associated with aging (Frontera, 2000). Mitochondrial oxidative capacity of the muscle is therefore further suppressed. Reductions in the cross-sectional area and capillary-to-fibre ratio have also been documented as common in relation to increased age (Frontera et al, 2000).

A possible explanation for this unexpected finding may be the age-related shift in proportion of type II muscle fibres to type I muscle fibres, with a relative increase in type I muscle fibres with increasing age (Frontera, 2000). As a result, aging is associated with a decrease in the motor unit discharge rate for a given force production. These age-related adaptations may therefore result in an increased time preceding task failure, and a reduction in the rate of development of peripheral fatigue with increasing age (Mademli et al, 2008). It may be hypothesized that these adaptations may protect against overload

of the muscle fibres, thereby minimising the incidence of muscle strains in older athletes. However, further studies are required to investigate this theory.

It is also possible that the age-related reduction in the incidence of muscle strains observed in this study may be due to a process of self-selection. The older canoeists participating in this event may be a self-selected group with a potential genetic predisposition and a superior ability to maintain levels of endurance training and competition. The process of self-selection may be associated with favourable adaptations related to a reduction in the incidence of injuries. However, this theory is speculative and requires further investigation.

No relationship was established between body mass index (BMI) and the incidence of injury. Previous studies have not identified BMI as a contributing factor in the development of injuries among canoeists (Schoen et al, 2002; Hagemann et al, 2004). This is a somewhat contrary finding as it is logical to assume that an increase in BMI might be associated with an increased risk of injury caused by a related increase in work rate. However this is an anecdotal observation that was not supported by the findings of this study. Moreover, Shepard (1987) established a link between BMI and performance in Olympic canoeists, where canoeists with better performances were above average in height and had an increased lean muscle mass. However, comparison of these results should be made with caution, owing to the major differences in the level of training status and competition between the sample groups of the current study and the Olympic sprint canoeists in Shepard's (1987) study.

In this investigation no relationship was established between training history, including the number of years spent canoeing and training hours in preparation for the Berg River Canoe Marathon, and the incidence of injury. This finding was somewhat unexpected, as du Toit et al (1999) had previously found that the incidence of forearm tenosynovitis was reduced in canoeists who had trained more than 100km per week in the eight weeks preceding the Berg River Canoe Marathon. Long-term endurance training may, furthermore, provide a protective adaptation against injury, through the relative increase in the proportion of slow-twitch fibres associated with repetitive endurance training (Lynch et al, 1997; Gonzalez et al, 2006).

No relationship between paddle length and incidence of injury was discovered in this investigation. This is a similar finding to that of du Toit et al (1999), suggesting that paddle length is not an extrinsic factor contributing to injury. Further studies should investigate the shaft circumference, the angle of the blade to the shaft, the type of paddle used and the composition of paddle material. Because of the nature of this study it was not feasible to introduce scrutiny of the myriad of variables which could be related to equipment.

The use of weight training during the six months prior to the Berg River Canoe Marathon was identified as a risk factor for the development of muscle strains. Significant relationships were established between the incidence of muscle strains and the selective use of weight training exercises, namely incline fly's, chin-ups with a weight belt, chin-ups without a weight belt, supine fly's, one-arm rows, and triceps-dips without a weight belt.

It has previously been noted that canoeists are at risk for developing increased soft tissue injury due to participation in weight-lifting training (Pelham et al, 1995). In the current study, the exercises identified as possible factors contributing to muscle strains all place the shoulder in positions of elevation or abduction. In these positions the glenohumeral joint is inherently biomechanically unstable and requires further dynamic stabilisation. The exercises that were associated with an increased risk of muscle strains all also strengthen the primary and secondary dynamic movers of the glenohumeral joint and do not address the stabilisers of the joint. Barlow et al (2002) indicate that weight-lifting exercises can predispose the shoulder to muscle imbalances increasing susceptibility to shoulder pathology. Although weight-lifting exercises were shown to improve strength on isometric strength tests of shoulder mobilisers, lower trapezius strength did not increase significantly. Lower trapezius acts as a stabiliser of the shoulder joint. Weight-lifting causes an imbalance in shoulder musculature, resulting in significant decreases in internal rotation range of movement (ROM) and an overall loss of shoulder ROM. Therefore, shoulder pathology predisposed by muscle imbalances is a result from weight lifting training (Barlow et al, 2002).

Furthermore, strength training itself can lead to injury. A combination of inadequate recovery time and excessive training load can result in overtraining or overreaching

(Brukner and Kahn, 2001). Symptoms of Overreaching include fatigue, mood changes and impaired performance. Added strength training when an athlete is overreaching can lead to further perpetuation of symptoms resulting in tissue failure or injury (Brukner and Kahn, 2001).

A significant negative correlation was found between the overall race position and the hours per week spent in canoeing training, suggesting that increased training hours resulted in improved performance. Endurance training has been said to improve endurance performance. Endurance-trained individuals have increased mitochondrial oxidative capacity and capillary density; adaptations which are related to improved oxygen extraction and utilization (Gonzalez et al, 2006; Lynch, 1997).

Similarly, a weak negative correlation was found between the number of years spent in canoeing and the overall race position, indicating that a longer history of training and participating in canoeing was associated with improved race performance. It then may be theorized that this finding may indicate a learning benefit, as previous years of racing may contribute to event experience, which may assist in minimising error during the event.

5.3 Limitations

The study design was limited to a broad investigation of the injuries sustained during the 2006 Isuzu Berg River Canoe Marathon. It is acknowledged that only 48 participants completed the study, possibly because daily sampling of the participants was required. Owing to the limited number of investigators available for data collection and the large number of participants finishing stages simultaneously, it was not possible to obtain daily data from all race participants.

Subjective bias was minimised by random allocation of investigators to participants in the study. However, owing to the nature of the field testing involved in this research, requiring questionnaires to be completed in harsh environmental conditions with the participants in a fatigued state, compliance during completion of the questionnaire may

have been compromised. This resulted in limited analysis of components of the questionnaire, particularly in relation to environmental factors.

5.4 Recommendations

It is evident that numerous extrinsic and intrinsic factors may contribute to the development of injuries in marathon canoeists. Further investigation of training and environmental factors that may contribute to injury is recommended. Future studies may be strengthened by an increase in sample size.

This exploration into the incidence of injuries in marathon canoeists identified some pertinent findings with regard to the incidence of exercise-associated muscle cramping, the relationship between injury incidence and age and the relationship between the incidence of muscle strains and weight training. However, this study design was unable to identify underlying mechanisms responsible for these observations. Therefore, further experimental research is recommended.

6 CONCLUSION

This study identified the most commonly injured areas in marathon canoeists participating in the 2006 Isuzu Berg River Canoe Marathon as being the hands (25%), shoulder (17.1%) and lumbar spine (11.4%). The most common injury types were muscle strains (30%), blisters (25%) and muscle cramps (20%). With regard to extrinsic contributing factors, there was a positive association between the incidence of muscle strains and selected weight training exercises (incline fly's; chin-ups with a weight belt, chin-ups without a weight belt, supine fly's, one-arm rows and triceps dips without a weight belt). The only intrinsic factor found to be associated with incidence of injury was age, with an increased risk of injury in younger canoeists.

This study has presented insight into the numerous types and areas of injury that may occur in a canoe marathon of this nature. Further experimental investigation of the underlying mechanisms associated with injuries is recommended.

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Appendix 1

Informed Consent Form

University of Cape Town

UNIVERSITY OF CAPE TOWN
DIVISION OF PHYSIOTHERAPY
MRC/UCT RESEARCH UNIT FOR EXERCISE SCIENCE AND SPORTS

INFORMED CONSENT

Dear Canoeist

The UCT Division of Physiotherapy and the MRC/UCT Research Unit for Exercise Science and Sports Medicine will be conducting a study to investigate the following:

- the incidence of injuries among marathon canoeists
- the relationship between paddle-shaft diameter and individual handgrip size and the development of tennis elbow and wrist pain in marathon canoeists
- the relationship between the lower back pain, lumbar range of movement and hamstring flexibility in marathon canoeists

The study will provide further insight into training, performance and injuries among marathon canoeists. In addition, it will provide a basis for future studies that aim to decrease the risk of injuries and improve performance in marathon canoeists.

The study will involve the following tests:

1. A baseline questionnaire
 - this will include questions regarding demographic information, medical and surgical history, training history, paddling history, boat information, and injury history
 - this questionnaire may be completed electronically before the 2006 Isuzu Berg River Canoe Marathon, or before the race at registration
2. At race registration (before the race) the following tests will be performed:
 - 2.1 the completion of the baseline questionnaire (if not completed prior to registration)
 - 2.2 body mass and stature measurements
 - 2.3 anthropometric assessment of body composition involving the measurement of skinfold thicknesses using skinfold callipers
 - 2.4 the diameter of your paddle and the size of your handgrip will be recorded using a tape measure
 - 2.5 the following tests will be performed to assess wrist function:
 - your elbow will be straightened and your wrist will be flexed to determine the presence of any pain

- you will then close your hand around your thumb, your elbow will be straightened and your hand stretched towards the little finger side of your hand again to determine the presence of any pain
- the maximal grip strength for each hand will be measured using a hand dynamometer. A dynamometer records the force produced by muscles

2.6 the following tests will be performed to assess lower back function:

- a questionnaire to determine the presence of any lower back pain and contributing factors
- the range of lower back movement will be measured using an inclinometer. This is a device that will be positioned over certain points on the spine. This device records degrees of movement. The range of flexion (bending forwards) and extension (bending backwards) will be recorded three times in order to obtain an average measurement
- the inclinometer will also be used to determine the degree of hamstring (back of thigh muscle) flexibility in both legs. This test will be performed in lying, with a strap over your pelvis to prevent movement during the test. A box will be placed under your thigh to maintain the hip at right angles during testing. The inclinometer will be held over a point on your knee. The knee will then be straightened as much as possible to determine the flexibility of the hamstring muscle. This test will be performed once on each leg. There may be slight discomfort (a sensation of a strong muscle stretch) during this test

3. At the end of each stage of the race, the following tests will be performed:

- 3.1 should any injury occur during any stage of the race, you will be asked to complete a questionnaire to determine the type of injury, the mechanism of injury, and any associated factors that may have contributed to the injury
- 3.2 you will be required to complete a daily "rating of pain" scale to monitor the injury during the race
- 3.3 if you develop wrist or elbow pain during any stage of the race, the wrist function tests (described above) will be completed
- 3.4 if you develop lower back pain during any stage of the race, the lower back function tests (described above) will be completed

Possible risks to subjects

There are no potential risks that may be associated with completing the questionnaire, mass, stature, skinfold measurements, muscle pain measurements, paddle size and handgrip measurements. During the wrist function tests, the only possible risk is the potential to cause muscle injury during the maximal grip strength test. However, this risk will be greatly minimised by thorough explanation of procedures, familiarisation of equipment and careful control of all testing procedures by an experienced investigator. During the lower back function tests, there is the risk of discomfort during the range of movement tests, and the hamstring flexibility test. This risk of discomfort will be minimised through thorough explanations, familiarisation, and control of the testing procedures by an experienced investigator.

Anticipated benefits to subjects

Subjects will receive a full summary of their individual results, as well as the overall findings from this study. Should subjects present with, or develop an injury during the 2006 Isuzu Berg River Canoe Marathon, advice and an exercise sheet will be given to assist with rehabilitation and to prevent further injuries from occurring.

Privacy and confidentiality

All records and results generated within this study will be stored in a computer database in a secure facility, and in a manner that maintains subject confidentiality. All participants will remain anonymous in any ensuing publication.

Contact Information

Investigator Name	Telephone	Email
Richard Feher	082 781 4403	richphysio1@worldonline.co.za
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Romy Parker	021 406 6571	rparker@uctqsh1.uct.ac.za

I confirm, if I complete the questionnaire electronically, that I have read and understood the informed consent form. I have contacted one of the investigators to have any questions explained to me. I understand that, if I complete the informed consent form and questionnaire electronically, that I will be required to sign a hard copy of the consent form at the 2006 Isuzu Berg River Canoe Marathon.

I confirm that the exact procedures and possible complications of the above tests have been explained to me. I understand that I may ask questions at any time during the testing procedures. I realise that I am free to withdraw from the study without prejudice at any time, should I choose to do so. I have been informed that the personal information required by the researchers will be held in strict confidentiality. In addition, I know that the information derived from the testing procedures will remain confidential and will be revealed only as a number in statistical analyses.

I have carefully read this form. I understand the nature, purpose and procedure of this study. I agree to participate in this research project of the UCT Division of Physiotherapy and the MRC/UCT Research Unit for Exercise Science and Sports Medicine.

Name (in full) of volunteer: _____

Signature of volunteer: _____

Name (in full) of witness: _____

Signature of witness: _____

Date: _____

2 Appendix 2

Baseline Questionnaire

University of Cape Town

**UNIVERSITY OF CAPE TOWN
BERG RIVER CANOE MARATHON STUDY**

INSTRUCTIONS:

- * This questionnaire is 6 pages long and consists of 7 sections
- * Please read each question carefully, as it is important that we obtain accurate information.
- * Please place information in the appropriate text box
e.g. Date of Birth: Day/Month/Year
- * If a question is asked, please place an 'x' in the appropriate text box
e.g. To which ethnic group do you belong?
 Black White Coloured Asian Indian Other
- * Please answer all questions as truthfully as possible. All personal information will be kept strictly confidential
- * If you have any questions, do not hesitate to contact us on:
Richard Feher 082 781 4403
Theresa Burgess 083 300 7763
Romy Parker 072 658 6836

SECTION ONE: PERSONAL DETAILS

- a. Name: _____
- b. Boat number: _____
- c. Contact number: _____
- d. Email address: _____
- e. Gender: Male Female
- f. To which ethnic group do you belong?
 Black White Coloured Asian Indian Other
- g. Date of Birth: _____ Day/Month/Year
- h. Height: _____ (cm)
- i. Weight: _____ (kg)
- j. Dominant hand: Left Right

SECTION TWO: MEDICAL HISTORY

- a. Have you ever been diagnosed with any of the following diseases?
- Asthma Renal disease Liver/gall bladder disease
- Diabetes High blood pressure High cholesterol
- Inflammatory Arthritis Tuberculosis Coronary artery disease
- Thyroid disease Osteoporosis Bilharzia/Schistosomiasis
- Osteoarthritis Cancer Other

If other, please specify: _____

- b. What medications did you, or do you take to treat these conditions?

Date	Disease	Medication

- c. In the last 3 months have you taken any medication, such as:
- Non-Steroidal Anti-Inflammatory Drugs (NSAID's)
- Pain-killers / analgesics

Please specify: _____

- d. Have you ever had surgery to any of the following:

- Lumbar spine Shoulder Wrist / hand
- Neck Elbow Lower limbs

Please specify: _____

SECTION THREE: TRAINING HISTORY**PLEASE ONLY INCLUDE YOUR HOURS OF PADDLING TRAINING****a. Routine practise schedule**

Average weekly training hours (hours/wk)
 Maximum weekly training hours (hours/wk)
 Minimum weekly training hours (hours/wk)
 Number of training days per week (days/wk)

b. In preparation for competition (e.g. Berg, Fish), if different to those above

Average weekly training hours (hours/wk)
 Maximum weekly training hours (hours/wk)
 Number of training days per week (days/wk)

c. Do you warm up prior to training/competition?

Yes No

d. If yes, how do you warm up?

Light aerobic exercise
 Walking
 Jogging
 Stretches

e. If you use stretching, please specify which muscle groups:

Lumbar spine Neck Elbow/wrist
 Thoracic spine/trunk Shoulder Lower limbs

f. How long, on average, do you hold each stretch?

5-10 seconds
 11-20 seconds
 21-30 seconds
 31-45 seconds
 46 seconds -1 minute

g. How many times, on average, do you stretch per week?

Once a week Once a day
 Twice a week Twice a day
 3 times a week 3 times a day
 4 times a week >3 times a day

SECTION FOUR: PADDLING HISTORY

a. Number of year paddling:

b. PADDLING HISTORY

Please complete the following table:

Event	Number completed	PB			Most recent performance		
		Year	Position	Time	Year	Position	Time
Berg							
Breede							
Dusi							
Fish							
Umko							
Drak challenge							
Vaal							
Lowveld croc							
8 km K1 timetrial							
10 km K1 timetrial							

c. OTHER EVENTS

Please complete the following table:

Event	Number completed	PB		Most recent performance	
		Year	Time	Year	Time
Two Oceans					
Cape Argus Cycle Tour					
Freedom Challenge					

SECTION FIVE: BOAT INFORMATION

a. Type of personal flotation device:

Polystyrene sheets Polystyrene balls Polystyrene strips

b. What boat are you using in the 2006 Isuzu Berg River Canoe Marathon?

c. Is this boat a simline? Yes No

d. What boats do you train in (including surfski's)?

e. Paddle type:

f. Paddle length: cm

g. Hand protection used:

Gloves Vaseline Dubbin Methyalate

h. Head protection used:

None Cap Helmet

SECTION SIX: PHYSICAL ACTIVITY PARTICIPATION

- a. We would like to find out about any other physical activities that you participate in. Below the table are examples of different activities. Please list (by number), any other sports that you regularly participate in.

Type of Sport	Months per year	No. of sessions per week	Duration of each session (hr:min)	Total hours per week

Examples of sporting activities:

- | | | |
|--------------|------------------------|-------------|
| 1. Jogging | 10. Aerobic dance/step | 19. Yoga |
| 2. Swimming | 11. Martial arts | 20. Pilates |
| 3. Cycling | 12. Volleyball | 21. Dancing |
| 4. Walking | 13. Strength training | |
| 5. Squash | 14. Hiking | |
| 6. Badminton | 15. Rock climbing | |
| 7. Netball | 16. Tennis | |
| 8. Soccer | 17. Golf | |
| 9. Rugby | 18. Skating | |

- b. Please indicate whether you have performed any of these specific strengthening exercises since January 2006:

- | | |
|--|---|
| <input type="checkbox"/> Latissimus pull-downs | <input type="checkbox"/> Upright rows |
| <input type="checkbox"/> Behind-the-head military press | <input type="checkbox"/> One-arm rows |
| <input type="checkbox"/> Inclined flyes | <input type="checkbox"/> Triceps dips with weight belt |
| <input type="checkbox"/> Supine flyes | <input type="checkbox"/> Triceps dips without weight belt |
| <input type="checkbox"/> Wide-grip bench press | <input type="checkbox"/> Chin-ups with weight belt |
| <input type="checkbox"/> French curls | <input type="checkbox"/> Chin-ups without weight belt |
| <input type="checkbox"/> Kayak (abdominal) twists with weight belt | |

SECTION SEVEN: PADDLING RELATED INJURIES

a. Have you ever experienced a paddling related injury?

Yes No

If Yes, please complete the following table:

Date of injury	Area of injury	Type of injury	Injury occurred during	Diagnosed by	Special Investigations	Time off training (weeks)	Management of injury	Did the injury resolve? Y/N	If No, for how long did it persist? (weeks)

Examples:
Lumbar spine
Thoracic spine
Neck
Shoulder
Elbow
Wrist/hand
Hip
Knee
Ankle/foot

Examples:
Muscle strain
Ligament sprain
Muscle cramp
Stress fracture
Tendon injury
Nerve
Dislocation
Fracture
Contusion

Examples:
In boat
Portage
Swim

Examples:
Self-diagnosed
Orthopaedic surgeon
Physiotherapist
Biokineticist
GP

Examples:
X-ray
Bone Scan
MRI

Examples:
Self-managed
Orthopaedic surgeon
Physiotherapist
Biokineticist
GP

3 Appendix 3

Daily Injury Questionnaire

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BERG RIVER CANOE MARATHON STUDY
DAILY INJURY QUESTIONNAIRE

DAY:

SECTION ONE: PERSONAL DETAILS

- a. Name:
- b. Boat number:
- c. Contact number:
- d. Gender: Male Female
- e. Date of Birth: Day/Month/Year
- f. Height: (cm)
- g. Weight: (kg)
- h. Dominant hand: Left Right

SECTION TWO: INJURY HISTORY

- a. Side of injury: Left Right
- b. Area of injury:
- | | | |
|---|---------------------------------------|--------------------------------|
| <input type="checkbox"/> Lumbar spine | <input type="checkbox"/> Elbow | <input type="checkbox"/> Knee |
| <input type="checkbox"/> Thoracic spine | <input type="checkbox"/> Wrist | <input type="checkbox"/> Ankle |
| <input type="checkbox"/> Ribs | <input type="checkbox"/> Hand | <input type="checkbox"/> Foot |
| <input type="checkbox"/> Neck | <input type="checkbox"/> Finger/thumb | <input type="checkbox"/> Toes |
| <input type="checkbox"/> Head | <input type="checkbox"/> Pelvis | <input type="checkbox"/> Skin |
| <input type="checkbox"/> Shoulder | <input type="checkbox"/> Hip | <input type="checkbox"/> Other |
- If other, please specify: _____
- c. Type of injury:
- | | | |
|--|--|-------------------------------------|
| <input type="checkbox"/> Muscle strain | <input type="checkbox"/> Muscle cramps | <input type="checkbox"/> Concussion |
| <input type="checkbox"/> Acute tendon injury | <input type="checkbox"/> Stress fracture | <input type="checkbox"/> Contusion |
| <input type="checkbox"/> Tendinopathy | <input type="checkbox"/> Fracture | <input type="checkbox"/> Laceration |
| <input type="checkbox"/> Ligament sprain | <input type="checkbox"/> Dislocation | <input type="checkbox"/> Abrasion |
| <input type="checkbox"/> Cartilage injury | <input type="checkbox"/> Subluxation | <input type="checkbox"/> Blister |
| <input type="checkbox"/> Bursitis | <input type="checkbox"/> Nerve injury | <input type="checkbox"/> Other |
- If other, please specify: _____

SECTION TWO: INJURY HISTORY (continued)

d. Any numbness / loss of feeling/ "pins and needles" in:

- Left leg Left bottom
 Right leg Right bottom

e. Injury occurred during:

- Portage
 Swim
 In boat

f. Time into stage when injury occurred:

- | | | |
|--|--------------------------------------|--------------------------------------|
| <input type="checkbox"/> 0-15 minutes | <input type="checkbox"/> 2.1-3 hours | <input type="checkbox"/> 6.1-7 hours |
| <input type="checkbox"/> 16-30 minutes | <input type="checkbox"/> 3.1-4 hours | <input type="checkbox"/> 7.1-8 hours |
| <input type="checkbox"/> 31-59 minutes | <input type="checkbox"/> 4.1-5 hours | <input type="checkbox"/> > 8 hours |
| <input type="checkbox"/> 1-2 hours | <input type="checkbox"/> 5.1-6 hours | |

g. Level of river when injury occurred:

- Low
 Medium
 High

h. Difficulty of rapid when injury occurred:

- Flat water
 Medium
 Strong

i. Which obstruction caused injury:

- | | |
|-------------------------------------|---|
| <input type="checkbox"/> Tree block | <input type="checkbox"/> Canoeist/equipment |
| <input type="checkbox"/> Bridge | <input type="checkbox"/> Other |
| <input type="checkbox"/> Weir | <input type="checkbox"/> n/a |
| <input type="checkbox"/> Rock | |

If other, please specify: _____

j. Were you wearing shoes when the injury occurred?

- Yes No

k. Were you wearing a helmet when the injury occurred?

- Yes No

l. Able to continue with next stage of race:

- Yes No

m. If unable to continue with next stage of race, indicate reason:

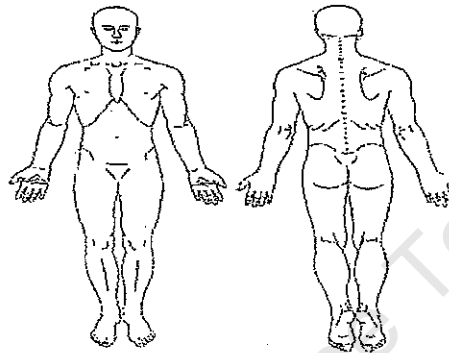
- Injury
 Damage to boat
 Other

If other, please specify: _____

Subject name: _____

Subject boat number: _____

On the diagram, shade in the areas where you feel pain. Put an **X** on the area that hurts the most.



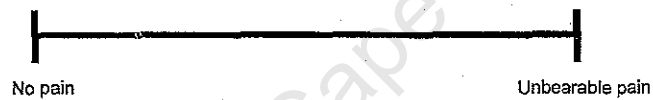
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Rating of pain

Please rate your pain *at rest* by drawing a vertical line along the axis below, in the position that best indicates your pain.



Please rate your pain *during paddling* by drawing a vertical line along the axis below, in the position that best indicates your pain.



Please rate your pain *during a stretch* by drawing a vertical line along the axis below, in the position that best indicates your pain.



Please rate your pain *when applying direct pressure to the area* by drawing a vertical line along the axis below, in the position that best indicates your pain.



**THE EPIDEMIOLOGY OF INJURIES SUSTAINED BY
CANOEISTS DURING THE 2006 ISUZU BERG RIVER
CANOE MARATHON**

Richard Feher

This dissertation is submitted in partial fulfilment of the award of the degree of
M.Phil (Sports Physiotherapy) at the University of Cape Town

Supervisors:

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Romy Parker

Cape Town 2009

Abstract

Aim: To establish the incidence of injuries sustained by canoeists during the 2006 Isuzu Berg River Canoe Marathon.

Methods: Male canoeists who qualified to compete in the race and were registered for the 2006 Isuzu Berg River Canoe Marathon were asked to volunteer for the study. Subjects were healthy volunteers aged between 18 and 65 years. Fifty-seven participants met the inclusion criteria and were included in the study. A baseline questionnaire was administered during race registration. A daily injury questionnaire was administered at the end of each stage of the 4-day event.

Results: Forty-eight of the study participants reported injuries (84.2%). Injuries were classified according to site and type. The most common sites of injury were the hands (25%), the shoulder girdle (17.1%) and the lumbar spine (11.4%). The most common types of injury were muscle strains (30%), blisters (25%) and muscle cramps (20%). Factors contributing to injury were analysed under intrinsic and extrinsic headers. The intrinsic factor of age was found to be associated with muscle strains. Canoeists who reported muscular strains were significantly younger than those who did not (33.8 yrs \pm 10.78 vs. 40.2 yrs \pm 10.76; $p = 0.03$). With regard to extrinsic factors, there was an association between weightlifting training and injury. Almost half of the participants ($n = 57$) used weightlifting training in the six months prior to this event (47.36%). Several types of weight training exercises were found to be associated with incidence of injury including; incline fly's ($p = 0.001$), chin-ups with a weight belt ($p = 0.014$), chin-ups without a weight belt ($p = 0.018$) supine fly's ($p = 0.026$) one arm rows ($p = 0.044$), and triceps dips without a weight belt ($p = 0.045$).

Conclusion: Canoeists participating in long distance multi-stage events appear to be at high risk for sustaining soft tissue injuries. Younger canoeists appear to be at particular risk for muscle strains. The use of certain weightlifting training exercises may be associated with soft tissue injury provocation.

Keywords

Canoe/Kayak injuries, Incidence, Questionnaire, Multiple day events/Marathons

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injuries, as well as the predisposing factors to injury. This is essential for effective injury prevention and management, in order to reduce the incidence of injuries, as well as time off training and competition. The results of the research are intended to contribute to a decreased future injury incidence at the Isuzu Berg River Canoe Marathon. They will, therefore, be communicated to the race organizers and relevant medical support staff.

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2 LITERATURE REVIEW

A search was conducted on literature relevant to canoeing and associated topics. Using the search engines of PubMed and the Health Science Library at the University of the Witwatersrand, a search was conducted. Keywords used were: canoeing injuries, swimming injuries, rowing injuries, multiple stage events, and marathon running injuries. The review covered relevant publications from 1970 to 2008.

2.1 Epidemiology

While little is known about the epidemiology of long distance canoeists' injuries in South Africa, the international literature does present some limited information highlighting major types, sites and causes of injuries in canoeists.

The studies that were reviewed predominantly covered the same boat types as seen in this research; the K1 canoes. The boat types being used in the 2006 Isuzu Berg River Canoe Marathon were the same class canoes as those surveyed (77.7%) by Kameyama et al (1999). A review conducted by Fiore (2003) mentions 6,5 million of the same style of canoe, while in a study by Krupnick et al (1998), 75% of participants used the same class of canoe.

In a large epidemiological study involving the Japanese Canoe Association, 821 canoeists were surveyed, using a sports injury questionnaire. Of the 417 canoeists who completed the questionnaire, 94 canoeists (22.5%) reported lumbar pain, 20.9% experienced shoulder pain, 10.8% wrist pain; and 3.8% elbow pain. The study covered a variety of racing styles, including kayak (n = 324), Canadian canoe (n = 71), slalom (n = 13), and others not specified. The majority of canoeists were men (n = 306), with 103 being women, and the remaining subjects' gender not noted. A variable not recorded in the study was whether the participants were sprint or marathon canoeists. The average canoeing career duration was 7.8 ± 3.6 years (range 2-20 years). These canoeists reported training for canoeing for 4.1 ± 1.6 hours (range, 2-8 hours) every day (Kameyama et al, 1999).

Kameyama et al (1999) conducted one of the most relevant studies related to canoeing. Despite the inability of the reader to discern between racing types and canoe techniques, this study gives a valuable general impression regarding the typical injuries seen amongst canoeists. Through the thorough reporting of demographics, the impression is given that the sport of canoeing is male-dominated and participants have varied experience and training regimens.

Further, physical examinations conducted on the Japanese sample revealed that the lumbar pain reported by participants (22.5%) was mainly myofascial in origin, whereas examinations revealed shoulder pain to stem from impingement, tendinopathy osteoarthritis and clavicular deformity. Examinations also revealed osteoarthritis in some of the canoeists suffering elbow pain (Kameyama et al, 1999).

In a systematic literature review of injuries sustained by white-water canoeists, blisters on canoeists' hands are noted as the main injury, with between 30% and 90% of canoeists suffering this soft tissue injury. From the studies surveyed, it was found that injury to the upper extremity was most common, with the shoulder the most likely joint to be damaged. The types of injury varied; the most prevalent being due to soft tissue overuse and shoulder dislocations. Although this review focused on white-water canoeists and not on K1 marathon canoeists, it showed relevance to the topic, since the 6.5 million canoeists comprising the sample were recorded as using craft in the same class as those used in the 2006 Isuzu Berg River Canoe Marathon. Canoeists surveyed in these studies participated on rivers graded from I to VI, which encompassed small waves, with no serious obstacles, to extremely difficult and high-risk rivers. The review makes the assumption that each canoeing day is 8 hours long; a similar length of canoeing day to that experienced by competitors in the Isuzu Berg River Canoe Marathon. The canoeists reviewed were almost 70% male, and overwhelmingly white (over 90%). Unfortunately, because of the retrospective nature of the studies involved, it was not possible to calculate true injury rates (Fiore, 2003).