Experimentally induced mechanical pain threshold and
tolerance difference between competitive contact and non-
contact sports male athletes

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I have always wondered why the “Acknowledgments” is placed at the first page when it is the last page to be written for a dissertation. It now has become so clear that this page provides a platform to express my gratitude to the many people that have helped me in the preparation of this dissertation and these people should be acknowledged right before the readers begin this journey with me.

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C.C. Ng

Abstract

Study Design: A single blind control experimental research, with repeated measures, on the difference in the experimentally induced mechanical pain threshold and tolerance between contact and non-contact sports male athletes.

Summary of Background data: In the past decade, there have been numerous investigations of pain in the athletic environment. Pain tolerance has been contended to be the most critical differentiator between successful and unsuccessful athletes in endurance sports. Athletes have been known to have better pain tolerance and threshold when compared to non-athletes. Contact sport athletes are particularly more prone to injuries that often cause acute and chronic pain. They are hence postulated to have higher pain tolerance. However, there is a lack of studies to support this concept. The empirical data from this current research will allow sport doctors, physiotherapists, sport psychologists, trainers and coaches to better manage injured athletes.

Aims: 1. To determine whether competitive male contact sport athletes have higher pain threshold and tolerance than non-contact sports male athletes, which might be associated with better pain management. 2. To determine the difference in mechanical pain threshold and tolerance between male athletes and non-athletes (as controls). 3. To determine the relationship between the “Visual Analog Pain Scale” (Pain-VAS) and pressure pain algometer.
**Methodology:** *Participants:* 15 male competitive contact sport athletes; 15 male non-contact sport athletes; and 15 male controls (non-athletes) were recruited.

**Intervention:** Participants were subjected to a mechanical pain pressure applicator (pressure algometer) till the onset of pain threshold and tolerance. Pain-VAS was also obtained.

**Statistical Analysis:** Data was analysed with the SPSS version 15 for Windows. ANOVA was used to evaluate the effects of contact and non-contact sports. Pearson product-moment of coefficient was used to evaluate the correlations of pain-VAS and pressure applicator.

**Result:** ANOVA showed that there was no significant difference in the contact sport athletes’ pain tolerance and threshold when compared to non-contacts sport athletes. Non-contact sport athletes had significantly higher pain tolerance level ($p = 0.044$) than non-athletes. Pain-VAS was only correlated to pressure algometer on pain threshold measurement ($r = 0.376, p = 0.011$).

**Conclusion:** Data from this current study does not support the wide belief that contact sport athletes have higher pain tolerance. More pain studies using different sport types are needed so as to examine the effect of sports on pain tolerance.
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Chapter 1: Introduction and Research Aims

1.1 Introduction

Athletes often suffer from sport injuries which can be threatening to their physical and psychological well-being (Danish, 1986). To live with minor or major injuries, and to practise or to play under pain seem to be an almost certain and acceptable part of athletes’ lives (Gauron & Bowers, 1986). Hence, athletes are often considered to have a higher pain tolerance when compared to the normal population (Cook & Koltyn, 2000; Addison, Kremer & Bell, 1998). The level of pain tolerance was found to be the most critical differentiator between successful and unsuccessful athletes in endurance sports (Iso-Ahola & Hatfield, 1986) and at the same time, a debilitating obstacle to effective sport injuries rehabilitation (Taylor & Taylor, 1998).

The International Association for the Study of Pain defined pain as an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage (Merskey & Bogduk, 1994). This definition highlights the duality of pain as a physiological and psychological experience. It is a physiological event within the body that is dependent on subjective recognition, that is, without psychological awareness, pain cannot exist.

The inherent capacity of the central nervous system to control the transmission of nociceptive (painful) afferent impulses, and thereby limit the perception of pain, has been a focus of considerable scientific activity since the publication of Melzack and Wall’s (1965) pain gate control theory. The resultant research by Cannon & Libeskind (1987), Lovick (1993) and Morgan et al. (1989) had highlighted the importance of endogenous pain control systems and demonstrated that endogenous analgesia is a multifaceted phenomenon involving a number of neuronal systems. Researches now
clearly demonstrate the important role for the rostral ventromedial medulla in facilitating the development of central sensitisation and hyperalgesia in inflammatory pain states (Urban & Gebhart, 1999). By up-regulating or down-regulating the nociceptive function, due to the influence of central systems projecting from the brain to the spinal cord and depending on the situational factors, will increase or decrease pain perception respectively. Investigators had studied pain reactions focusing on sensory endings, nerve tracts and stimulus intensities (Cook & Koltyn, 2000), conscious and unconscious attitudes as well as feelings and motivations toward pain. In other words, evaluation of reactivity to pain has been approached from the neurological, physiological, cultural and psychoanalytic points of view (Straub et al., 2003).

Athletes are known to have better pain tolerance and threshold when compared to non-athletes (Whitmarsh & Alderman, 1993). However, there are studies that refute this concept. The discrepancies are due to the types of noxious stimulus imposed on the subjects. Athletes have been shown to be less sensitive to noxious cold and more tolerant to ischemic stimulation and noxious pressure than non-athletes but there is no difference in their response to noxious heat (Hall & Davies, 1991; Janal et al., 1994).

Manning and Fillingim (2002) employed three experimental pain applicators (pressure threshold, cold pressure pain and tolerance, and ischemic pain threshold and tolerance), together with a series of psychology inventories and demographic questionnaires, to examine the influence of the athletic statuses and genders on experimental pain responses. On the whole, they found no significant effects of pressure and ischemic pain threshold between athletic statuses and genders although athletes had demonstrated significantly higher tolerance for ischemic pain as well as cold pressure pain threshold and tolerance when compared to non-athletes. As for the effect of gender differences, male athletes were found to have higher level of pain threshold and
tolerance to cold pain when compared to their female counterparts but the differences in the pain levels were not significant, suggesting that both males and female athletes have similar physiological or psychological characteristics.

Studies on the psychometric pain management techniques and strategies used in athletes and non-athletes were unable to distinguish the frequency and type of coping strategies between the two groups (Azevedo & Samulski, 2003). They evaluated the pain intensity, frequency and duration as well as the coping strategies, using a questionnaire (SBS-V), on 160 subjects (80 athletes and 80 non-athletes) and were looking for possible associations between preferred coping style and pain intensity of athletes and non-athletes of both genders. The results show that athletes and non-athletes, regardless of gender, used the same frequency coping strategies. Hence, the possible explanation that athletes can better endure pain due to the higher use of pain control psychological techniques seems unlikely and thereby, brings back the discussion that physiological differences might be the cause of higher pain tolerance and control.

Contact sport athletes are particularly prone to injuries that often cause acute and chronic pain (Anshel & Russell, 1994). Athletes participating in contact sports are found to exhibit higher pain tolerance than those involved in non-contact sports (Ryan & Foster, 1967; Ryan & Kovacic, 1966). Straub et al. (2003), using the Pain Apperception Test, showed that there was statistically significant difference in pain perception in athletes involved in contact and non-contact sports. The contact athletes, having better pain perception, are able to manage pain better during sports.

To-date, the only experimental study that examined mechanical pain threshold and tolerance between contact and non-contact sport athletes was by Ryan and Kovacic (1966). Their study has been widely referred to by many subsequent pain researches in athletes, stating that contact sport athletes have higher pain threshold and tolerance
when compared to their counterparts (Straub, Martin, Williams & Ramsey, 2003; Broucek & Bartholomew, 1993; Focht, Bouchard & Murphey, 1998). In their study, Ryan and Kovacic (1966) used a gross pressure device, consisting of a flat, rubber coated, football cleat secured to a plastic, foam padded, soccer shin guard. The cleat was placed midway between the ankle and the knee, on the medial surface of the tibial. The sleeve of a standard clinical sphygmomanometer was used to secure the device and induce pressure. Since then, there is no replication of the type of study like Ryan and Kovacic (1966). Broucek & Bartholomew (1993) employed the same pressure pain applicator method as in the study by Ryan and Kovacic (1966) to examine the effects of relaxation and warning signal prior to the onset of pain stimulus on pain tolerance of contact sport athletes and non-athletes. Subsequent pain studies in the athletic population on pressure pain instead have used modern validated pressure pain applicators, like the algometry (Antonaci, Sand & Lucas, 1998; Persson, Brogardh & Sjolund, 2004). However, none of the studies grouped the athletes into contact sports and non-contact sports for comparison.

This current research aims to repeat the experiment by Ryan and Kovacic (1966) and at the same time, address and control a few research methodology concerns regarding their study.

1.2 Purpose of Study

The objective of this study is to examine the difference in the experimentally induced mechanical pain threshold and tolerance between competitive contact and non-contact sports male athletes. The aims of this study are:
1. To determine whether competitive contact sports male athletes have higher mechanical pain threshold and tolerance than non-contact sports male athletes, which might be associated with better pain management.

2. To determine the difference in mechanical pain threshold and tolerance between male athletes and non-athletes (as controls).

3. To determine the relationship between the “Visual Analog Pain Scale” (pain-VAS) and pressure pain applicator.

1.3 Significance of Study

The significances of this study are:

1. Self reports of pain during competition may not be a true reflection of the extent of injury if an athlete has higher pain tolerance. Failure to attend to real or potential tissue damage could impair recovery and healing, diminish athletic performance and can ultimately lead to chronic pain conditions. The empirical data from this study will allow the clinicians to make an evidenced choice when managing injured athletes.

2. Allows for future development of pain coping strategies and management.

3. Development of rehabilitation strategy for treatment of contact and non-contact sport athletes.

1.4 Hypothesis

The hypotheses of this research study are:

1. There will be significant difference in the pressure pain threshold and tolerance between controls, competitive contact sport athletes and non-contact sport athletes.
2. There will be significant difference in the pain perception (pain-VAS) between the controls, competitive contact sport athletes and non-contact sport athletes.

3. There will be significant difference in the relationship between the pain-VAS and pressure pain applicator.

1.5 Assumptions

The basic assumptions of this study are:

1. Participants will report pain threshold and tolerance as instructed.

2. Participants will adhere to the procedures as stated in the “Informed Consent Form”.

3. Participants will truthfully report their status as stated in the inclusion and exclusion criteria.

1.6 Limitations

The limitations of this study are:

1. Due to the nature of the experiment, results of the study cannot be directly generalised to on-field situations.

2. The study’s results cannot be generalised to non-competitive athletes and recreational athletes as only competitive athletes are examined.

3. Only athletes from two types of sports (i.e. Rugby and Track and Field) are examined. The study cannot be generalised to other types of sports.

1.7 Delimitations

The delimitations of this study are:
1. Female athletes are excluded from the study to eliminate the effects of hormone on pain perception. Women’s pain threshold was found to be significantly higher during the second phase of the menstrual cycle (Hellstrom and Lundberg, 2000; Unruh, 1996; Chesterton et al, 2003; Edwards et al, 2003; Myers et al, 2001; Berkley, 1997; Garofalo et al, 2006; Keogh & Birkby, 1999; Manning & Fillingim, 2002). Hence, only male athletes are recruited.

2. All psychological and behavioural aspects of pain are not examined in this study.

3. Cleland, Palmer and Venzke (2005) found that ethnic and cultural differences have an effect in pain perception. They ascertained that diverse ethnic groups express the quality and intensity or frequency of pain differently. Participants’ race is recorded but not analysed as this is not the main aim of this study.

1.8 Study Design

This study used a single blind experimental research, with repeated measures, to examine the difference in the experimentally induced mechanical pain threshold and tolerance between contact and non-contact sports male athletes. The tester is blind to the types of sports that the study’s participants engaged in. Measurements are repeated on three separate occasions.

1.9 Operational Definitions of Terms

The operational terms of this study are:
1. Mechanical “Pressure Pain Threshold” (PPT). PPT is defined as the point at which a sensation of pressure changes into a sensation of pain (Andersen et al., 2006). This is measured with a pressure algometer.

2. Mechanical “Pressure Pain Tolerance” (PPTO). PPTO is defined as the point at which the maximum pain tolerated (Andersen et al., 2006). This is measured with a pressure algometer.

3. Visual Analog Pain Scale (Pain-VAS). Pain-VAS is the report of one’s subjective perception of pain intensity. This is measured with a 100 mm line VAS scale.

4. Competitive contact and non-contact sports will be based on the classification as proposed by Dyment et al. (1988). Competitive contact sports are defined as sports that have high degree of strenuousness and collision/contact. Non-contact sports are sports that have no contact or collision. The latter can be divided into strenuous, moderately strenuous and non-strenuous non-contact sports.

1.10 Independent Variable

The independent variable of this study is the sport type, i.e. competitive contact sports and competitive non-contact sports.

1.11 Dependent Variables

The dependent variables of this study are:

1. Mechanical PPT. Measured by pressure algometer (Unit: kg/cm²).

2. Mechanical PPTO. Measured by pressure algometer (Unit: kg/cm²).

3. Pain-VAS. Measured by VAS scale (Unit: mm).
1.12 Moderating/Extraneous Variables

The moderating/extraneous variables of this study are:

1. Previous injury/injuries history and intensity of injuries to test sites will be assessed by the tester and recorded. Participants with any acute injuries to the test sites, as assessed by the tester, will not be tested on the test date.

2. Participants with abnormal pain behaviour and history of chronic pain will be excluded from the study. Petzke et al. (2005) showed that subjects with chronic pain suffering from fibromyalgia displayed less relative unpleasantness than healthy controls in response to random noxious pressure stimuli. Their study results are consistent with the concept that chronic pain may reduce the relative unpleasantness of evoked pain sensations.

3. Stress induced analgesia from competition can alter pain perception. Sternberg et al. (1998) showed that competition modulates behaviour response to noxious stimuli. However, the degree and direction of this modulation (inhibition or potentate) depends on the pain test, the body region tested and the sport in question. There was no difference in competition related change in pain sensitivity between males and females. Hence, participants will be required to report their immediate competition schedules to the tester during or before the testing dates. No testing will be conducted two days before or after any competitions.

4. James and Hardadottir (2002) studied the combined effects of attention focus and trait anxiety on tolerance in acute experimental pain. Pain tolerance was greater when participants were distracted and in low rather than high anxiety participants. To reduce distraction, the experiment venue will be in a quiet environment.
and confined environment. To reduce anxiety, participants will be briefed on instruction of the procedures and followed by a trail run on the elbow to prepare the participants.

5. Kallai, Barke and Voss (2004) investigated the effects of two attributes of the experimenter (gender and professional status) on the report and tolerance of pain in male and female subjects. They showed that pain was tolerated longer when tested by a professional. Both male and female participants, when tested by opposite sexes, reported higher pain tolerance. For this current study, participants will be informed on the professional status of the tester as a physiotherapist. The tester is a male.

1.13 Intervening Variables

The intervening variable of this study is psychological inputs that will affect pain tolerance and threshold.

1.14 Control Variables

The control variables of this study are:

1. Cigarette smokers have been found to have significantly increased cold pressure pain tolerance and threshold when compared to non-smokers (Girdler et al., 2005). Participants will be told not to smoke or consume alcohol 24 hours prior to testing.

2. Participants who have participated in previous similar pain studies will be noted and results will be analysed subsequently.

3. Informing the participants on the purposes and nature of the study will reduce participants’ pain perception of the experiment. However,
participants will not be informed on the direction of the tests or intended test results (e.g. higher pain tolerance is related to higher reading on pain applicators and less value of the pain-VAS score).

1.15 Summary

The lack of experimental study on pain tolerance on different sports athletes has led to the formulation of this current study’s research question: Do contact sport athletes have better pain tolerance when compared to non-contact sport athletes? Now, with better validated tools and knowledge in experimental pain application, this study aims to test the notion that contact sport athletes have higher pain tolerance as claimed in the available literature. The next chapter will examine current pain science and review pain literature in the athletic population.
Chapter 2: Literature Review

2.1 Introduction

In the past decade, there have been numerous investigations of pain in the athletic environments. Pain is a serious warning symptom that places a decisive limit on sports capability, particularly with high performance athletes (Prokop, 2000). Using a pressure pain applicator, Brewer, Van Raalte and Linder (1990) found support for the hypothesis that pain would inhibit motor performance as a function of task complexity. They reasoned that pain induces a state of over-arousal which in turn, negatively affects the performance of difficult tasks. In many sports such as rugby or boxing, the ability to withstand pain appears to be essential to successful performance, while in sports such as tennis or golf, the ability to withstand pain would be less important. Thus, it is not inconceivable that an individual’s ability, or inability, to tolerate pain may well determine the category of sports he or she selects (Ryan & Kovacic, 1966).

Athletes and non-athletes appear to differ in their pain responses. More specifically, athletes are known to have better pain tolerance and threshold when compared to non-athletes (Whitmarsh & Alderman, 1993; Azevedo and Samulski, 2003) as they usually deal with injuries and pain. Manning and Fillingim’s (2000) study demonstrated a significantly higher ischemic and cold compressor pain threshold and tolerance among athletes than non-athletes. Using the cold compressor test, Sullivan et al. (2000) examined the differences in pain perception in varsity athletes and sedentary controls. They found that the athletes reported less pain than sedentary individuals, and male athletes reported less pain than female athletes. However, there are studies that contradict all these findings. For example, Paparizos et al. (2005) found that athletes
have similar pain threshold when compared to non-athletes, although they have higher pain tolerance and the exact cause is unknown.

The literatures have noted that different types of sports athletes have different pain perception. With more physical insults as well as strenuous training and injuries, contact sport athletes are believed to exhibit higher pain tolerance than those involved in non-contact sports. Ryan and Kovacic (1966) was the only study that examined the pain perception in these two groups of athletes. Using a controversial pain assessment procedure, they found that contact sport athletes tolerated more acute pressure pain and significantly longer than non-contact sport athletes. The contact sport athletes are particularly exposed to injuries that often cause acute and chronic pain (Anshel & Russell, 1994), which might be a reason for their increased pain tolerance. This is in accordance to the “adaptation-level theory”, which implies that painful experiences can change the internal anchor points for subjective evaluation of pain. Dar, Ariely and Frenk (1995), who studied 40 male war veterans, were able to support this theory with their research result. They found that those veterans who had been severely injured had much higher threshold and tolerance for thermal pain as compared to lightly injured veterans. This implies that athletes who had injuries before or often will tend to tolerance pain better.

Recent pain studies challenge the “adaptation-level theory”. Studies (Song et al., 1999; Woolf, 1984; Johansen et al., 1999) have demonstrated the development of mechanical hypersensitivity and persistent pain in animals and humans following injury. Shortly after the onset of injury and pain, alterations in tissue sensitivity may occur in response to neurobiological and biopsychosocial influences (Carr & Goudas, 1999). Pain complaints in unrelated body regions and spontaneous exaggerated pain outside the neuro-anatomical sensory distribution of the suspected lesion may follow sensory
threshold changes. This shift in pain processing may be responsible for ongoing pain or decreasing the pain tolerance (Urban & Gebhart, 1999). This controversial information again highlights the complexity of pain and humans’ response to pain, which might improve or limit motor performance.

2.2 Pain Science

Today, pain is viewed as a complex psycho-bio-social phenomenon, in which an individual’s perception of (sensory system) and response to (affective system) pain is influenced by a variety of subjective experiences (Hirsch & Liebert, 1998). Pain is hence a sensation that is composed of distinct yet inter-related dimensions. Pain can be described in terms of its intensity or sensory qualities as well as its emotional or affective aspects, which are integral to the sensation. Primary affective pain is believed to occur over a short period of time and is related to the minute by minute appraisal of pain, whereas secondary affective pain involves both past and future long-term reflection of the sensation or condition. A final cognitive-evaluative dimension integrates both past experiences and judgements, and exerts control over activity of both the sensory and affective systems (Petzke et al., 2005).

The following section will provide a platform in the understanding of the pain and the current concepts in pain science. It is out of the scope of this paper to explain these concepts in great detail. Readers can refer to pain textbooks for further readings.

2.2.1 Pain Receptors

The receptors for pain are called nociceptors and are free nerve endings. The primary sensory neurones involved in transmitting pain are Aδ, C and Aβ fibres (Oliver & Ryan, 2004). Type Aδ fibres are small myelinated fibres which are capable of
transmitting acute or fast pain messages. The pain produced is instant, sharp and localised. Type C fibres are very small unmyelinated fibres that transmit messages at a slower rate. The pain is dull, throbbing and is not localised. Type Aβ fibres are not directly related to the transmission of pain messages. They are situated in the skin and have a rapid conduction activated by touch and sensation. All these fibers will interact to produce different types of pain. Aronson (2002) wrote a paper reviewing three common pain theories in the pain literatures. They are the Pain Gate Control Theory, Central Biasing Pain Theory and Endogenous Opiates Pain Theory.

2.2.1.1 Pain Gate Control Theory

When a noxious stimulus is induced, pain carrying Aδ nerve fibers in the peripheral nervous system are activated first and start to move the message (bright local pain) toward the spinal cord at a rate of approximately 15 m/s. Activation of C nerve fibers send a slow pain message (slow, dull and diffuse pain) at a conducting speed no faster than 2 m/s that follows the same pathway. Both pain messages proceed to the substantia gelatinosa which is located within the spinal cord. This is also referred to as Laminae 2 and 3 or the dorsal horn.

Melzack and Wall’s came up with the gate control theory of pain. Using a gate as an analogy, the substantia gelatinosa is a “gate keeper” that determines whether a sensory message will reach the brain or be blocked. The pain message will release substance P at the substantia gelatinosa and open the gate. This in turn sends signals to the T cells, which transport the message via the spinothalamcic or spinoreticular tract in the spinal cord. The message ascends to the reticular formation, which is part of the brainstem that influences alertness, waking, sleeping and reflexes (Gilman & Newman, 1992). When the reticular formation is stimulated, autonomic motor and sensory
responses are quickly produced (Buxton, 1999). This produces the pain threshold, which is the determinant of the first pain felt as a function of the reticular formation. Once the cortex (central brain) perceives the sensory message of pain, it will react by sending efferent messages down the spinal cord. These descending tracts of messages can either be exaggerated or inhibited by inducing a non-noxious stimulus via afferent Aβ nerve fibers. The Aβ nerve moves the message so fast (at a rate of 70 m/s) that it will reach the gate in the substantia gelatinosa more quickly than the next painful stimulus. The new message via the Aβ will block the “gate” and prevent substance P produced by the Aδ or C nerve fibers to reach the T cells. Hence, in short, the gate control theory of pain states that non-painful stimuli can block painful stimuli.

2.2.1.2 Central Biasing Pain Theory

Central biasing pain theory explains the concept of “learned behaviour” (Starkey, 1993). It is built on the pain gate control theory and addresses brain influences on incoming and outgoing messages. Cognitive effects can alter sensory discrimination, the location of the pain source, the intensity of the pain and the nature of the pain (Prentice, 1999). The central biasing pain theory has a motivational-affective influence. An internal drive or external stimulation can have a strong influence on thought processes and therefore, affect the perception of pain. The ascending message of pain passes through the reticular formation, the thalamus and may enter the limbic system which then links the motivational and emotional responses to the pain message (Gilman & Newman, 1992). This explains the different emotional responses to pain, i.e. fear, rage, crying, panic, denial and anxiety, and control to pain. Hence, pain tolerance, which is the maximum degree of pain intensity a person is willing to experience, should take in consideration the cortex of the athlete’s brain, the limbic system, reticular formation and
the thalamus. These brain structures interpret the intensity of pain, send autonomic responses, regulate pain threshold and modify the emotional response to pain. This suggests that pain response appears to be more physiological than psychological in origin (Watt-Watson, 1999). Moreover, culture, ethnicity, socioeconomic status, type of sport played (contact vs non-contact), personality type and being in the ‘heat of the game’ will all influence pain tolerance (Buxton 1999; Prentice, 1999).

The central biasing pain theory is applied to athletic training or therapy when an athlete self rates his or her pain on a “Visual Analog Pain Scale” (pain-VAS) (Buxton, 1999). Studies have shown poor correlations between patient’s self reported pain and the assessment of patient’s pain by others. The implications of these findings are that pain severity must be assessed through patient’s reports rather than replying on external indicators or other criteria (National Health and Medical Research Council, 1999). This strengthens the use of the pain-VAS to assess pain. This current study will use the pain-VAS to obtain an objective measure of the participants’ pain severity reports during the experiment.

**2.2.1.3 Endogenous Opiates Pain Theory**

Castel introduced a theory of pain after endogenous opioids were discovered in the human body in the 1970s (Pretice, 1999). The body produces three types of peptides that have opioid-like properties: enkephalins, endorphins and dynorphins (Lehne, 2001). Upon injury to tissue, bradykinin, prostaglandin and substance P are released. These mediators influence the initial inflammatory response to injury. Bradykinin directly produces painful stimuli. Prostaglandin and substance P lower the nerve’s threshold to bradykinin, which magnifies the perception of pain.
In the spinal cord, opioid peptides are released to modulate pain transmissions (Gilman & Newman, 1992). Methionine enkephalin also influences the release of pain modulators. Enkephalins are natural endogenous opiates found in the central nervous system that are released rapidly for short term pain relief (Buxton, 1999; Prentice, 1999). They counteract the effect of substance P in the substantia gelatinosa and thus inhibit the transmission of painful stimuli to the T cells (Watt-Watson, 1999).

Endorphins originate from the hypothalamus which is where pain threshold is influenced (Buxton, 1999). The thalamus directs the sympathetic nervous system to gear up for “fight” or “flight”, which involves the release of norepinephrine/adrenaline. Norepinephrine and adrenaline both have effect on improving pain perception. With severe stress and physical exertion, beta-endorphins, one of the norepinephrine, are released in the cerebral spinal fluid and provide up to four hours of natural pain relief (Starkey, 1993). This will hence provide athletes with better pain tolerance to injuries and physical athletic demands.

2.3 **Athletes and Pain**

Pain is a central aspect of involvement in physical activity and sport (Sullivan et al., 2000). While sports professionals have generally been found to have higher pain threshold than control subjects, the reasons for this are not entirely clear (Tajet-Foxell & Rose, 1995). Researchers have attempted to provide explanations for athletes having higher pain threshold and tolerance. The reviews of these researches are presented below:
2.3.1 Exercise Induced Analgesia

Dramatic anecdotes from dancers (Paparizos et al., 2005) and athletes, who continue strenuous exercise in the face of severe injuries and later report they felt no pain, have contributed to the notion that exercise can alter pain perception. Some investigators have referred this as “Exercise Induced Analgesia” (EIA) (Koltyn, 2000).

However, in almost all of the studies that have been conducted in this area, investigators have reported diminished sensitivity to noxious stimulation during and following exercise (hypoalgesia) rather than a complete absence of pain (analgesia) (Koltyn, 2002). The International Association of the Study of Pain indicates that analgesia refers to the “absence of pain on noxious stimulation”, whereas hypoalgesia refers to “diminished sensitivity to noxious stimulation” (Merskey & Bogduk, 1994). Hence, “Exercise Induced Hypoalgesia” has been suggested to be a better terminology over EIA. Most literatures however still use the term, EIA.

Over the past 20 years, a number of studies have examined whether analgesia occurs following exercise (Koltyn 2002, 2000). The most commonly tested hypothesis for EIA has been that activation of the endogenous opioid system during exercise may be responsible for the analgesic response that occurs following exercise (Koltyn, 2000; Guieu et al., 1992). The endogenous opioid peptides of beta-endorphin have been shown to affect the analgesic and the emotional systems (Janal et al., 1984), but whether or not this peptide has any physiological functions is still uncertain.

Heitkamp, Schmid & Scheib, (1993) said that intensive physical exercise, while stimulating the circulating beta-endorphin level, is independent of the exercise duration. However, Koltyn’s (2002) review on exercises found this hypothesis to have mixed data in human researches and more consistent in animal researches for EIA. In animal
studies, endogenous opioid peptides are found to produce their analgesic effects through the activation of opioid receptors located in the hypothalamic region (Richardson, 1990), and hardly at the central nervous system as the blood-borne endorphins penetrate poorly into the blood-brain barrier of the central nervous system. This suggests that animals seem to produce EIA at a central level. In contrast, human beings seem to activate EIA effects at the peripheral level as human studies shown a connection between peripheral beta-endorphin level and exercises (Denko et al., 1982; Szyfelhein, Osgood & Carr, 1985). Plasma beta-endorphin, having anti-nociceptive effects, could be a maker for potential analgesic activity.

Oktendalen et al. (2001) investigated the possible correlation between increase in circulating blood level of beta-endorphin and decrease in pain perception after a short term maximum oxygen uptake (VO$_{2\text{max}}$) treadmill exercise. Pain perception, which was measured by ischemic pain test and a blood analysis for beta-endorphin, was performed before and after the VO$_{2\text{max}}$ test. Their study showed significant increase in plasma beta-endorphin and decrease in pain perception in response to the VO$_{2\text{max}}$ test.

Hoffman et al. (2004) recommended researchers to examine both the intensity and duration of exercise to determine the “optimal dosage” of exercise that are required to produce hypoalgesia. Results are less consistent for studies that prescribed exercise based on percentage of heart rate maximum, as well as for studies that let participants self select the exercise intensity. Kendall, Borgeson, Karlsson and Gerdle (2003), who studied the effect of a single moderately-intensive 60 minutes exercise session on 24 healthy women’s pressure pain thresholds, had also confirmed this notion. They found no change in pressure pain sensitivity at any of the tendon, bone and muscles sites, following a pre- and post-exercise pressure pain stimulus.
Koltyn’s (2002) systematic review on EIA found that hypoalgesia occurs consistently after high-intensity exercise. Hypoalgesia was found most consistently with a workload of 200Watts (W) and above, and following exercise prescribed at a percentage of maximal oxygen uptake (e.g. 60 –75%) (Cramer, Nieman & Lee, 1991). Koltyn et al. (1996) in their study used 75% VO$_{2\text{max}}$ to assess changes in pressure pain threshold and pain rating following exercise. 14 men and two women completed 30 minutes of cycle ergometry exercise at 75% VO$_{2\text{max}}$. The results indicated that pressure pain threshold and rating were altered following exercise. Pain threshold was found to be significantly higher while pain rating was found to be lower after exercise. Hoffman et al. (2004) took a convenient sample of 12 healthy males and females to study the effect of pain rating and threshold following different exercise intensity at 75% and 50% VO$_{2\text{max}}$. There was a significant decrement in pain rating five minutes after an exercise bout of 30 minutes at 75% VO$_{2\text{max}}$ but no significant effect was found after 10 minutes of exercise of the same intensity or after 30 minutes of exercise of a lower intensity. Hoffman et al. (2004) concluded that both a minimal exercise intensity and duration are required to elicit EIA.

Drury et al. (2005) in their study showed that hypoalgesic response can only be produced during exhaustive exercise. They put 17 healthy female athletes, of average aerobic capacity, through a graded exhaustive VO$_2$ peak cycling challenge. It was found that pressure pain threshold and tolerance were significantly elevated only at VO$_2$ peak compared to a workload of 120W. However, Focht, Bouchard and Murphey (1998) gave contradicting results about exercise intensity to produce EIA. They found that through 14 weeks of low aerobic intensity martial arts training, pain tolerance can be improved. This suggests that the type of exercise might be important to produce EIA rather than the intensity of exercise.
The effect of aerobic and strength training on pain tolerance, pain appraisal and mood of unfit males, as a function of upper and lower limb pain locations was studied by Anshel and Russel (1994). Unfit males (n = 48) were randomly assigned to one of four groups: aerobic training, strength training, combined aerobic and strength training, and “no training” (control) group. The training regimens consisted of exercising at least three times per week for 12 weeks. The subjects’ pain tolerance, pain appraisal and mood were assessed before the treatment, and after six and 12 weeks of treatment.

MANOVA analysis indicated that aerobic training increased upper limb pain tolerance and improved vigor while decreasing fatigue, tension and depression. Strength training, however, had no influence on pain tolerance and positive mood states, but increased depression. Lower limb pain tolerance was also unaffected by the treatment.

It is conceivable that intensities of exercise required to produce hypoalgesia may differ for individuals who are not experiencing pain and individuals with various chronic pain conditions. Most athletes might be injured at one point of time or are experiencing chronic pain through their sporting careers (Anshel & Russell, 1994). What dosage of exercise would be optimal for them to induce hypoalgesia? There are still not many studies on this area (Koltyn, 2002). Hoffman et al. (2005) did the first experimentally induced pain perception study on the effect of aerobic exercise in people with chronic low back pain. Their study was able to demonstrate that aerobic exercise in people with minimal to moderate disability from chronic low back pain has increased tolerance to experimentally induced pressure pain. Their study also suggested that the mechanism for the observed EIA is related to a systemic process as the painful stimulus was distant from the exercising muscles. Hoffman et al. (2004) suggested that pain inhibition is a central phenomenon rather than at the peripheral level. Their study testing sites were on the upper limbs when exercises were performed on the lower limbs. They
were able to show evidence that pain tolerance had increased in the upper limbs, suggesting a central pain inhibition effect. Drury et al. (2004) also supported the concept proposed by Hoffman et al. (2004). Their study findings on pain threshold difference in 20 male subjects doing isometric and cardiovascular exercises with force dolorimeter suggested that systemic alterations that accompany sub-maximal large muscle group exercise seem to have a greater influence on EIA in comparison to the local and systemic effects of repeated isometric contractions of muscle. The changes in pain threshold were also positively correlated to heart rate, blood pressure and growth hormone levels (Hoffman et al., 2004).

There have been a number of different noxious stimuli used in the laboratory to produce pain in EIA researches. The work by Janal et al. (1994) provides some support for the notion that the perception of pain from different stimuli may not be closely linked. They observed no correlation between measures of perception of heat, cold, ischemic and electrically induced pain. It appears that analgesia following exercise is found more consistently in studies that used electrical or pressure stimuli to produce pain, and less consistently in studies that used temperature (Koltyn, 2000, 2002). Guieu et al. (1992) employed electrical stimulation on the sural nerve to assess changes in the threshold of the nociceptive flexion reflex following cycle ergometer exercise on athletes and non-athletes. Pain threshold, was assessed at rest and following 20 minutes of cycling, in eight non-athletes and six high level athletes who regularly participated in national or international athletic competitions. Pain threshold was found to be significantly higher in the athletes compared to the non-athletes while they are at rest.
2.3.2 Stress Induced Analgesia

The brain is a powerful modulator of sensory input. In the pain modality, the central nervous system mechanisms play an active role in the inhibition of nociceptive afferent fibers. Effectively producing analgesic states when in perception of pain would be detrimental to survival. Such reduced sensitivity to noxious stimuli can be activated by acutely stressful environmental events, termed as “Stress Induced Analgesia” (SIA). The ability of athletes to continue to compete despite sustaining painful injury during competition is anecdotal evidence of the natural occurrence of SIA in humans outside laboratory setting (Sternberg et al., 1998). Athletic competitions are likely to produce analgesia due to the psychological and physical stresses via the arousal of the sympathetic nervous system.

There have been studies examining the effect of athletic competitions on pain perception. For instance, Sternberg et al. (1998, 2001) examined changes in pain perception following athletic competition of three different sports (i.e. basketball, fencers and track runners). Male and female basketball players, fencers and track runners were exposed to cold pressure and noxious heat before and following an athletic competition. Cold pressure ratings were found to decrease significantly immediately following athletic competition and there were also changes in withdrawal latencies to noxious heat stimuli. It was shown that different components of the competitive athletic experience might be responsible for the analgesic effects in a sex dependent manner (Sternberg et al., 2001).

Sternberg et al. (1998) evaluated experimental pain sensitivity in 36 males and 33 female collegiate athletes two days before, immediately following and two days after competition. When comparing these athletes to 20 matched non-athlete controls, they found that competition induces both hyper-analgescic and analgesic states in athletes, but
these were dependent on the body region tested, pain assessment methodology and sport in question. However, there was no difference in competition related changes in pain sensitivity between males and females.

Scott and Gijsbers (1981) studied pressure pain tolerance of elite (high aerobically conditioned), non-elite (low aerobically conditioned) swimmers and non-competitive (leisure) swimmers. Pain threshold was shown to be of little difference between the groups but pain tolerance was considerably different. The pain tolerance of the competitive swimmers was considerably different and varied according to the stage of the training season. Non-elite swimmers were found to endure more pain than non-competitive swimmers.

In an attempt to separately assess the hypoalgesic effects of the cognitive stress associated with competition, as compared with the physical exercise component, Sternberg et al. (2001) examined changes in pain perception and assessed the cold pressure pain rating in 41 athletes following: competing in a track meet; competing in an auto racing video game competition and running for 10 minutes on a treadmill at 85% of maximum heart rate (HRmax). Cold pressure pain rating was also assessed in 22 non-athletes following the video competition and treadmill exercise. Their results indicated that pain rating decreased following the athletic competition in male and female athletes. Treadmill running produced a hypoalgesic response in women (independent of athletic status) but not in men. Pain rating, however, was found to decrease following the video game competition in men, but not in women. All the findings seem to suggest that males are more task-orientated and thus have heightened SIA mechanisms.

Mitchell, MacDonald and Brodie (2004) however cautioned the reliability of cold pressure testing. They found that a small variation in the water temperature of a
cold pressure test would result in significant differences in both pain intensity levels and
tolerance times. Tolerance times were found to be significantly longer with a difference
of four degree when tested on healthy subjects. The rating given on the pain-VAS was
significantly higher with a difference of two degrees. A survey of previous studies using
the cold pressure revealed a lack of standardisation and control of water temperature,
thus questioning its comparability and reliability (von Baeyer, 2005). The problem with
cold pressure task is the unavoidable ceiling effect. An increase in pain is only
experienced up to the point at which numbness occurs. In addition, athletes might have
accustomed to the ice pressure task as they are routinely exposed to ice as part of injury
management.

2.3.2.1 Effect of Fear and Anxiety

Competition can evolve the feeling of fear and anxiety. Fear and anxiety are
both stressors to the body and hence could induce SIA. It has been suggested that pain is
ameliorated by fear but exacerbated by anxiety. Fear has been conceptualised as an
emotion elicited directly by an actual event (e.g. experience of a noxious stimulus),
whereas anxiety is a future-oriented emotion elicited by a potential event (e.g. threat of
pain). It has been argued that fear and anxiety may be qualitatively different emotional
states mediated by two distinct neural circuits (Davis, Walker & Lee, 1997).

Eccleston and Crombez (1999) stated that fear of pain and catastrophic thinking
about pain produce a general hypervigilance for pain and a priming of escape behaviour.
People, when threatened by pain, have the propensities to catastrophise about pain,
engage in less cognitive coping strategies and show reduced tolerance during exposure.
Self reported appraisals of threat have been linked to reduced tolerance for experimental
pain (Stanford et al., 2002). Rhudy and Meagher (2000) had suggested that fear, due to
the actual experience of shock in their experiment, might have led to attentional resources being diverted away from the test stimuli, thereby producing higher pain threshold in the fear condition. Fear might also have an effect in increasing pain tolerance. It is hence vital that the pain stimuli in experimental settings should not provide SIA effect as it will give a false positive result. Hoffman et al. (2005) was able to show that the pressure pain testing itself does not evoke a significant SIA effect with their study on subjects with chronic low back pain and healthy control subjects.

James and Hardardottir (2002), who examined the separate and combined effect of attention focus and trait anxiety on tolerance of acute experimental pain on 500 undergraduate and graduate students, found that distraction could increase pain tolerance. In addition, pain tolerance was greater in persons who reported low rather than high trait anxiety. Their study also showed that pain tolerance was greatest when no external distraction was used with low anxious participants whereas high anxious participants were least pain tolerant under the same condition. This suggests the notion that anxiety fosters attentiveness to possible environmental threats.

Since anxiety can provoke an increase in pain perception, controlling this emotion using relaxation technique could influence an athlete’s perception of pain during task performance and be beneficial in mitigating the negative effects of pain on performance (Breer, Van Raalte & Linder, 1990). Broucek and Bartholomew’s (1993) study showed that relaxation has the effects of improving athletes’ pain tolerance level. This however has yet to be fully established in either athletic or clinical settings. For example, although Keefe et al. (1990) had proved that relaxation and imagery can reduce the perception of pain in osteoarthritic subjects, it was not shown to effect task performance in terms of speed and ease of daily movement. On the other hand, Oktedalen et al. (2001) examined the effect of regular meditation to control pain on 20
physically trained males before and after a six-month intervention period while
practising regular physical endurance training. Their study showed that using meditation
to control anxiety from physical training does not increase the basal plasma level of
beta-endorphin in the subjects’ blood tests. Increased beta-endorphin level is related to
decrease in pain perception via the explanation of the Endogenous Opiate Pain Theory.

2.3.3 Psychological Differences

Numerous studies have established a strong relationship between level of pain
and physical/psychological dysfunction (Kremer & Atkinson, 1981; Macchi &
(i.e. diverting attention, ignoring pain) were associated with the ability to function
physically and psychologically. Therefore, an athlete’s attitude toward pain and
strategies used while experiencing pain may subsequently be reflected in his or her level
of athletic performance and adherence to prescribed medical care.

Studies in pain control suggest two main factors that contribute to pain control:
self efficacy and use of psychological copying strategies. Self efficacy has been defined
as the belief in one’s ability to organise and perform in order to achieve one’s goal
(Bandura, 1997). Self efficacy has been identified as a potentially important mediator of
pain tolerance. In both laboratory (Baker & Kirsch, 1991; Bandura et al., 1988) and
clinical studies (Altmairer et al., 1993; Jensen et al., 1991; Litt et al., 1995), self efficacy
has been shown to be a significant predictor of coping effort and subsequent pain.
Rokke et al. (2004) performed a study on 101 undergraduate psychology students to
examine the effect of self reported self efficacy level and the choice of coping strategies
on level of pain tolerance. Choice and self efficacy were positively associated with
increases in perceived control. Being given a choice, in comparison to having no choice,
leads to increased tolerance and lower pain reports for those with high self efficacy. Providing a choice of coping strategies however did not benefit those with low self efficacy. Hence, Rokke et al. (2004) suggested that the benefits of allowing individuals the opportunity of choosing among the array of coping options must be dependent on a prior conviction that one is able to cope.

In endurance sports, there is an element that all athletes who wish to excel must confront, i.e. pain. There are three types of pain: emotional, injury related and pain as the result of an intense prolonged energy-expanding effort (Kress & Statler, 2004). Athletes see pain as something to overcome rather than to be feared. Kress & Statler (2004) study on cyclists found that the subjects feel that perception of pain is a choice and pain is part of the sports. The cyclists also feel that pain is a condition that they know would end in a short amount of time. Athletes, who have higher self efficacy, different coping strategies and perceived ability to control pain, are more accustomed to pain than non-athletes (Keogh & Birkby, 1999). Athletes, who have developed effective coping strategies for tolerating higher levels of injury-free pain, are expected to perform better than those who have not (Azevedo & Samulski, 2003; Egan, 1987; Masters & Ogle, 1998).

The use of psychological techniques (coping strategies) has shown to be effective in pain control. Haythornwaite, Menefee and Clark (1998) defined these techniques as “an attempt to deal with or manage a specific stressor” and they can be behavioural or cognitive. Addison et al. (1998) developed an integrative model which links the physiological sensation of pain with a two-stage process of cognitive appraisal and a series of behavioural responses, which are mediated by extrinsic and intrinsic factors together with cognitive coping strategies. Fernandez and Turk (1989) did a meta-analysis on the utility of cognitive coping strategies for altering pain perception.
and revealed that 85% of the investigations showed that cognitive strategies have a positive effect in enhancing pain tolerance/threshold or will attenuate pain ratings as compared to no treatment and placebo manipulations. Imagery strategies tended to be the most effective, whereas strategies involving repetitive cognitions or acknowledgement of sensations associated with pain were among the least effective.

Kress (1999) studied former Olympic cyclists’ cognitive strategies for coping with pain during performance. Using inductive content analysis, he uncovered several higher order themes that are associated with pain management: pain, preparation, mental skills, mind and body, optimism, control as well as “house in order”. He concluded that the degree of pain is purely a perception. Physically and mentally prepared cyclists experienced less pain than their counterparts who were lacking in these qualities. Paparizos et al. (2005) when examining cognitive appraisal of pain catastrophising across dancers and non-dancers found no significant difference between the two groups and deduced that ballet dancers and non-dancers catastrophised responded similarly to pain. Previous research investigating catastrophising of athletes looked at a heterogeneous sample including runners, volleyball players, equestrians, etc (Sullivan et al., 2000) and gave contradicting results in their studies compared to Paparizos et al.’s (2005) study. This suggests that cognitive mechanisms involved in appraising pain experiences may be dependent on the nature of their sports.

Pain tolerance was correlated with a number and quality of coping strategies used during testing. Ord and Gijsbers (2003) experimentally induced ischemic pain on 20 male competitive rowers and controls and found that the rowers have higher pain tolerance but not threshold. They reported using a range of self-generated pain coping strategies, which they used at training, during testing. However, Azevedo and Samulski (2003) showed no difference between athletes and non-athletes of both genders in
relation to the frequency of use of psychological techniques for pain control in their study. Hence, the explanation for athletes to better endure pain due to higher use of pain control psychological techniques is not supported. On the other hand, physiological testing of elite endurance athletes does not completely account for differences in performance (Bosquet, 2002), hence, suggesting that psychological factors might still play an important role in the achievement of outstanding endurance performance. Most psychological studies use non-experimental designs and unmeasured variables (e.g. self esteem, locus of control and neuroticism) which cannot be dismissed as potential causes of both appraisal and coping response in pain studies.

Straub et al. (2003) studied the difference in contact and non-contact athletes’ pain perception by using a projective technique with the “Pain Apperception Test” (PAT) designed by Petrovich (1957). The PAT is used for the assessment and evaluation of psychological variables involved in the experience of pain. Straub et al. (2003) found that contact sport athletes have lower pain perception than non-contact sport athletes. It was found that track and field athletes experience higher apperception of pain than lacrosse and soccer players. Ziesat and Gentry (1978) noted that although the face validity of PAT is adequate, their study on 55 chronic pain patients showed that the PAT lacks concurrent validity. Using a different assessment procedure, Ryan and Kovocic (1966) reported that contact sport athletes tolerated acute pain significantly longer than non-contact sport athletes. It is likely that the contact sporting experience helps athletes manage pain and may be an influential variable in contributing to pain apperception differences among the athletes.
2.4 Pain Study

The early work of Smith et al. (1966) on experimentally induced ischemic pain, cited by Mitchell, MacDonald and Brodie (2004) states that the ability to administer noxious stimuli under experimental conditions is widely recognised as an invaluable tool in the investigations of analgesic manipulations. Researches have showed that athletes have a higher pain tolerance and report lower pain intensity than non-athletes (Ahern & Lohr, 1997). However, whether athletes really have better pain tolerance and threshold when compared to non-athletes are still inconclusive (Whitmarsh & Alderman, 1993). The discrepancies in pain studies in athletes seem to be due to the types of noxious stimulus imposed on the subjects. Athletes have been shown to be less sensitive to noxious cold, and more tolerant to ischemic stimulation and noxious pressure than non-athletes, but no difference in their response to noxious heat (Hall & Davies, 1991; Janal et al., 1994). Thermal and electrical stimuli selectively activate skin nociception whereas pressure stimuli target both at skin and deep tissue nociceptors with a relative preponderance of the latter ones (Kosek et al., 1999; Rollman & Lautenbacher, 2001). Information from deep tissue nociceptors are processed differently in the spinal cord than that from superficial tissue nociceptors. With the spinal input from deep tissue nociceptors being subjected to stronger descending inhibitory control compared to skin nociceptors (Mense, 1993), there will be an increase in pain modulation. This might give more meaningful information about pain control in the athletic environment.

Hastie et al. (2005) evaluated subgroups emerging from multiple experimental pain measures. Their study used 188 subjects (59% female) who completed several psychological instruments and underwent ischemic, pressure and thermal pain assessments. 13 separate pain measures were obtained by using the three experimental
pain modalities with several parameters tested within each modality. The pain ratings and scores were submitted to factor analysis that identified four pain factors from which “Pain Sensitivity Index” (PSI) scores were computed. Cluster analyses of PSI scores revealed four distinct clusters. The first cluster demonstrated high overall pain sensitivity, the second cluster revealed high temporal summation of heat pain, the third cluster showed particular insensitivity to ischemic pain and low sensitivity across pain modalities except for pressure pain, and the fourth cluster demonstrated low sensitivity to pressure pain. These analyses revealed that groups respond differently across varied pain stimuli and this was not related solely to demographic or psychological factors. This highlighted the need for further investigation to identify patterns of responses across different pain modalities in order to more accurately characterise individual differences in response to experimental pain.

To-date, the most valid examination of pain is still that of one’s subjective report of pain. Williamson and Hoggart (2005) did a systematic review on Pain Rating Scale of VAS, Numerical Rating Scale and Verbal Rating Scale. They found that all these scales are reliable and valid. The pain-VAS is the most robust as it provides ration level data. Olaogun et al. (2004) also examined the pain-VAS and the “Semantic Differential Scale” (SDS) in patients with low back pain on a flexion task. They showed strong intra-tester correlations for VAS and SDS. This suggested that SDS is reliable and valid for rating of pain (in this case low back pain) as well.

None of the studies reviewed critic on the validity of the objective measurement of pain perception except for the pressure pain algometry. The latter is the most well examined and validated modality in pain studies. Antonaci, Sand and Lucas (1998) found that the mechanical pressure algometer is a good and inexpensive tool for assessment of pain perception thresholds. It has been reported to have good
reproducibility even with repeated testing over 15-minute intervals and across days (Hoffman et al., 2004)

Antonaci, Sand and Lucas (1998) found good inter-examiner reliability with Intraclass Correlation (ICC) of 0.75 and intra-examiner excellence with an ICC of 0.8. Prior studies of pressure pain threshold reliability had demonstrated Pearson Correlation Coefficients ranging from .65 to .96 for intra-rater reliability (Nussbaum & Downes, 1998; Reeves, Jaeger & Graff Radford, 1986) and from .47 to .89 for inter-rater reliability (Reeves, Jaeger & Graff Radford, 1986; Chung, Um & Hyung, 1992). The examiner needed to be skilled in order to get inter-examiner repeatability (Persson et al., 2004). Nussbaum and Downes (1998) found that two examiners agreed well on average pain pressure threshold but there could still be a large difference between them when assessing individual subjects. Antonaci et al. (1998) found inter-examiner reliability to be good but lower compared to intra-examiner reliability.

Parameters such as pressure rate and pressure application angle have been reported to affect the reliability (Antonaci et al., 1998) and might be an important factor explaining parts of the inter- and intra-reliability. This variability in inter-rater reliability may be related to the tissue consistency beneath the test site and the ability of the examiner to obtain proper perpendicular alignment of the algometer due to the anatomical restrictions related to the test site itself. Kosek et al. (1993), who examined pressure pain threshold in healthy women, found differences in different body regions and between tissues; for example, muscle belly, tendon insertion and periosteum are easily measured. In this study, the medial aspect of the tibial shaft was chosen as the test site as it has a rather flat surface and has no muscular tissue beside the skin. This test site allowed for perpendicular algometer positioning. Another parameter that has influence on pressure pain threshold measurements is the size of the stimulating probe.
Studies aiming at activation of nociceptors in skin or deep tissue have found thresholds correspond according to the probe size (Greenspan and McGillis, 1994). When small probes (0.01-0.49 mm²) are used, there is little effect on afferents in deeper tissue and mainly the intra-epidermal nerve ending will be activated (Treede et al., 2002). Activation of mainly deep afferents is possible only when the pressure is exerted with large (e.g. 1 cm²) padded probes. This current study employs a 1 cm² probe.

In summary, the pressure algometry has been well established to have high validity and reproducibility in many studies of different tissues and sites on the body.

2.5 Summary

This chapter has described the proposed mechanisms: EIA, SIA and athletes’ psychological status that researchers used to explain the difference in pain perception in athletes. The current studies in the area of pain science in sports are mostly related to athletes and non-athletes. No studies as highlighted in this review have examined the difference in contact and non-contact competitive sports athletes except for the study by Ryan and Kovacic (1966). Contact sport athletes are thought to have higher pain tolerance due to the amount of injuries and nature of the contact sports involved. Studies have suggested that athletes within the different sports types might exhibit different mechanical pain tolerance and thus coping strategies.

This current study will control the variables of EIA, SIA and psychological factors so that it will only examine the pain effect of the type of sports the athletes participate in, namely contact and non-contact sport. The next chapter will describe the procedure.
Chapter 3 Methodology

3.1 Introduction

This chapter outlines the methods used and design of the study. There will be a discussion on the independent, dependent and mediating variables, and the selection of the participants. The instruments to be used as well as data collection and statistical analysis procedures will also be explained.

3.2 Variables

The independent variables of this study were competitive contact sports and competitive non-contact sports. The dependent variables of this study were:

1. Mechanical “Pressure Pain Threshold” (PPT). Measured by pressure algometer (Unit: kg/cm²).
2. Mechanical “Pressure Pain Tolerance” (PPTO). Measured by pressure algometer (Unit: kg/cm²).
3. “Visual Analog Pain Scale” (pain-VAS). Measured by VAS scale (Unit: mm).

3.3 Participants

A stratified random sampling method was employed for the recruitment of participants for this study. The participants were grouped as:

1. CCS: competitive contact sport male athletes (Rugby: Focus is on the skill, speed team cooperation, endurance and physical contact).
2. CNCS: competitive non-contact sport male athletes (Track and field athletes: running in different track events. Focus is on the nature of competition, as in athletes are competing against a clock, rather than against one another).

3. CTL: controls (Non-athletes, healthy males).

CCS and CNCS participants were recruited by:

1. A letter or email invitation to participate in the current research was extended to all Singapore competitive sport clubs and/or universities (See Appendix 1: Letter of Invitation for Research Participation and 1.1: Participants’ Information Sheet).

2. Advertisement of recruitment via posters in universities.

CTL participants were recruited by:

3. Advertisement of recruitment via posters in universities/schools (See Appendix 2: Advertisement Poster).

3.3.1 Inclusion Criteria

Inclusion criteria for CCS and CNCS participants were:

1. Healthy male athletes who are currently in competitive contact or non-contact sports (strenuous) as defined by Dyment et al. (2001) (See Appendix 3: Classification of Sports).

2. Athletes have to be competing in the same sport and have been in competition for at least two years.

3. Age between 21 years to 35 years on the date of recruitment.
Inclusion criteria for CTL participants were:

1. Healthy males who are not currently participating or had not participated in competitive sports.
2. Healthy males who are not involved in more than 30 minutes of exercises and who exercise less than three times per week.
3. Age between 21 years to 35 years on the date of recruitment.

3.3.2 Exclusion Criteria

Participants who are found to have any of the following were excluded from this study:

1. Any known physical, psychological or systemic medical conditions that will enhance or decrease pain perception or tolerance.
2. Impaired mechanical sensation as tested by the “sharp/blunt” test.
3. On any medication(s) that will or might affect pain perception or tolerance.
4. Cannot understand the procedures of the study even when explained by the investigator.

3.4 Instruments

The pressure algometer

Pain threshold (PPT) and pain tolerance (PTO) were assessed with a pressure algometer (made commercially available by Pain Diagnostic and Thermography Corporation, Pain Threshold Meter, Model PTH-AF2). The apparatus consists of a 1 cm diameter hard rubber tip, attached to the plunger of a pressure (force) gauge. The dial of the gauge was calibrated in kg/cm². The instrument was also
calibrated at the start of the testing and the zero level balanced before each measuring session. The inter tester and between tester coefficients of repeatability had been tested and found to be significantly reliable (Anatonaci, Sand & Lucas, 1998, Fisher, 1988).

**Pain-VAS scale**

The Visual Analog Pain Scale was measured with the Pain-VAS scale. The pain-VAS assesses the participants’ subjective perception of the amount of pain. The pain-VAS was presented as a 100 mm line, anchored by verbal descriptors, usually 0 mm as “no pain” and 100 mm as the ‘worst imaginable pain’. Participants were asked to mark on the 100 mm line to indicate their pain intensities. The score was measured with a standard ruler from the zero anchored to the participants’ marks.

The Pain-VAS scale has been found to be validated as well as reliable and appropriate for the use of clinical assessment of pain (Williamson & Hoggart, 2005) and experimental pain research. It is sensitive to both pharmacologic and non-pharmacologic interventions to reduce pain (Belanger, Melzack & Lauzon, 1989) and has a high association with pain measured on verbal and numeric pain-rating scales (Ekblom & Hansson, 1988).

**Self perceived pain tolerance/ competitiveness levels and contact level Visual Analog Scale**

Using Visual Analog Scale technique similar to the pain-VAS, participants were asked to rate their self perceived pain tolerance level, self perceived
competitiveness level (for participants of CCS and CNCS only) and self perceived contact level in the sport (for CCS participant only). These VAS scores however have not been used in other studies and hence are not validated. They are assumed to be based on the principles of the pain-VAS. The self perceived competitive-VAS used was a 10 cm long scale, which 0 cm indicates the minimum perceived level of competitiveness and 10 cm indicates the maximum perceived level of competitiveness. Similarly, the self perceived contact level-VAS used was a 10 cm long scale, where 0 cm indicates the minimum perceived level of contact and 10 cm indicates the maximum perceived level of contact. As for the self perceived pain tolerance-VAS, it was also a 10 cm long scale, where 0 cm indicates the minimum self perceived level of pain tolerance and 10 cm indicates the maximum self perceived level of pain tolerance. The scores were measured with a standard ruler from the zero anchored to the participants’ marks.

3.5 Procedures

Firstly, ethics approval was obtained from the National Institute of Education, Singapore, Physical Education and Sport Science’s ethical review board. (See Appendix 4: Approval from NIE, PESS). Secondly, in order to fund the research, a research grant was obtained from the Singapore Physiotherapy Association (SPA), Singapore. (See Appendix 5: SPA Research Grant Application Form).

Participants were recruited for the study upon receiving the signed informed consent form (See Appendix 6: Informed Consent Form). The recruitment of participants was performed by a research assistant as that the investigator would be blind to the participant’s grouping
3.5.1 Description of Procedures

1. Participants were required to complete a personal information form and questionnaire (See Appendix 7: Participant’s Information Form).

2. Participants were blinded to the investigator, i.e. investigator did not know which group the participants belonged to. The examiner’s expectancy had been shown to affect pain threshold measurements mainly at control sites (Ohrbach, Crow & Kamer, 1998). The investigator is a male. There was a significant interaction of the experimenter’s gender to the subjects as subjects were found to tolerate pain longer when they were tested by an experimenter of the opposite sex. Additionally, subjects also showed higher pain intensities when tested by female experimenters (Kallai, Barke & Voss, 2004).

3. Before the start of the experiment, participants received explanations and instructions on the concepts of pain threshold and tolerance, experiment procedures, instruments used and what to expect and how to respond. The instructions given were:

Algometer Test

“For the assessment of pain threshold, you will be exposed to a mechanical pressure with the tip of the algometer on your shin bone. Say “now” when you start to feel painful and the pressure applied will be stopped. Inform the investigator how much you would rate this pain by marking on the pain-VAS score. This test will be repeated on three different spots on your shin bone for two times.”
“For the assessment of pain tolerance, you will be exposed to a mechanical pressure with the tip of the algometer on your shin bone. Say “now” when the pressure applied on you is too painful to tolerate and the test will stop immediately. Rate your pain level by marking on the pain-VAS pain score. This test will be repeated on three different spots on your shin bone for two times.”

4. A trail was performed on the participants’ left lateral epicondyles to ensure that they understood the testing procedures.

5. The participants were asked for their dominant limbs. A coin was tossed to decide if the dominant limb would be used at the first test. If so, the alternate limb would be tested in the second testing session and back to the same limb on the third testing session. In healthy subjects, PPT has been found to be highly correlated to the right and left sides of the body with only small differences in mean pressure (less than 0.27 kg/cm²) (Hogeweg et al., 1992; Fischer, 1987). Hence, this suggests that either limb may give similar PPT results.

6. The participants were seated on a height adjustable plinth. The testing limb was exposed and the ankle joint placed in neutral position on a chair so that the tibia would be perpendicular to the floor. The investigator palpated and marked the distal end of the tibial tuberosity. A 10 cm distance from distal end of the tibial tuberosity was measured with a measuring tape and marked. A 1 cm distant medial to the most prominent structure of the tibia from this mark point was located and named as point D. Two more points would be marked, 1 cm above and below point D, and named as D+1 and D-1, respectively. The three points were taken for measurement at each test
session. The testing site was chosen for a few reasons. Firstly, the tibial tuberosity is prominent and easy to palpate. This allows for good reproducibility in locating the anatomical landmark for all testing sessions. Secondly, there is no variance to soft tissue volume as the tibial shaft is most prominent regardless of the size of the participants. This eliminates the factor of soft tissue size in different participants. Thirdly, bone injury/pressure is more painful than that on soft tissues. This is due to the periosteum having the lowest pain threshold of the deep somatic structures (Ekman & Koman, 2004). Kosek, Ekholm and Hansson (1999) studied PPT in different tissues, in no particular body region, of 15 healthy women and found no difference in pressure threshold between muscle site and bony site, but muscle/nerve site had a lower PPT. The relationship remained unaltered by skin hypoesthesia, and hence suggests that skin sensitivity has no bearing on the PPT results.

7. Two rounds of testing on each point were performed. The first round of testing was discarded as the first reading is generally higher than consecutive measurements (Farella et al., 2000). The mean of the three readings taken from the second round was calculated and used as this has been shown to improve reliability (Ohrbach & Gale, 1989; Takala, 1990; Pontinen, 1998). The same procedure was repeated for the next two subsequent testing sessions.

8. The investigator was seated in a position where his right hand was holding on to the algometer and resting against his sternum. He located the point of application, took up any soft tissue slack with his left hand and was ready to
apply force through the algometer via his body and not by the hand. This allows a constant pressure application rate to reduce variance (Jensen, 1986).

9. The pain threshold tests were done and completed before the pain tolerance tests. Each time, the investigator would ask the participants if they were ready before application of the algometer. The participants rated each pressure test while the investigator read the algometer’s readings and recorded the tests’ readings on the record sheet. The VAS rating was not shown to the investigator during the testing so as to prevent any biases by the investigator (Ohrbach, Crow & Kamer, 1998). A resting interval of 15 seconds between each measurement was given. Several researches were able to show that consecutive measurements of PPT over the same point reveal little variation and small measurement effects with repeated pressure application to the same point (Ohrbach & Gale, 1989; Jensen et al., 1986; Nussbaum & Downes, 1998). Repeated measurements with short intervals show stable intra-individual PPT values when the first measurement is excluded (Persson, Brogardh & Sjolund, 2004).

10. Participants were given an ice pack to apply on the test site post test. They were advised to monitor the test area for any complain of tissue swelling and report to the investigator on the next testing session.

11. Another physiotherapist (also as the research assistant) was present at all test sessions as requested by the research ethics requirement.

3.6 Data Analysis

A single-blind experimental design, with repeated measures, was used for this current study. To evaluate the effect of repeatability of the testing instruments,
Intraclass Correlation Coefficient (ICC) was used. The Analysis of Variance (ANOVA) was used to examine the effect of contract sports on athletics pain threshold and tolerance. Furthermore, to evaluate the relationship of pain-VAS and pressure testing, Pearson product-moment coefficient of correlation was used. All statistical results were tabulated using the Statistical Package for the Social Sciences v15 (SPSS; Norusis/SPSS Inc., Chicago, USA). The value of alpha for significance was set at 0.05 throughout.
Chapter 4 Results

4.1 Introduction

In this chapter, all statistical results are tabulated using the Statistical Package for the Social Sciences v15 (SPSS; Norusis/SPSS Inc., Chicago, USA). Analysis of variance (ANOVA) is applied to investigate the effects of contact sport on athletes’ pain threshold and tolerance levels. The criterion for statistical significance is set at $p < 0.05$. Post-hoc comparisons are performed using Tukey ‘honestly significant differences’ (HSD) test. Mean values and standard deviations are also calculated. In addition, Pearson correlation tests are used to assess the relationship between the “Visual Analog Pain Scale” (pain-VAS) and the pressure algometry.

4.2 Descriptive Statistics

45 participants, who met the study’s inclusion and were not within the exclusion criteria, were recruited and all of them completed the study. They were grouped into three groups of 15: contact sport athletes (CCS); non-contact sport athletes (CNCS) and non-athletes as the control group (CTL). CCS participants are Rugby players and CNCS participants are track and field runners. Both groups of athletes are actively competing in clubs and/or university competitions within their own sport types at the point of this study.

Table 1: Demographics and anthropometric characteristics across the three groups of research participants

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>CCS (n = 15)</th>
<th>CNCS (n = 15)</th>
<th>CLT (n = 15)</th>
<th>All participants (n = 45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Age ± SD (Year)</td>
<td>22.4 ± 1.2</td>
<td>25.5 ± 4.2</td>
<td>24.6 ± 2.3</td>
<td>24.2 ± 3.4</td>
</tr>
<tr>
<td>Mean Body Mass ± SD (kg)</td>
<td>81.3 ± 9.3</td>
<td>66.9 ± 5.8</td>
<td>68.7 ± 8.1</td>
<td>72.2 ± 10.0</td>
</tr>
<tr>
<td>Mass Height ± SD (m)</td>
<td>1.77 ± 0.08</td>
<td>1.72 ± 0.03</td>
<td>1.74 ± 0.06</td>
<td>1.74 ± 0.06</td>
</tr>
</tbody>
</table>
Table 1 presents the descriptive statistics of the research participants. The mean (SD) age of the 45 participants was 24.2 (3.4) years old; mean height (SD) was 1.74 (0.06) m; mean weight (SD) was 72.2 (10.0) kg and Body Mass Index (BMI) (SD) of 23.7 (3.0) kg/m$^2$. There are significant differences in age, weight and BMI across the three groups. Post hoc analyses using the Tukey test revealed that participants in CCS were significantly younger than those in CNCS ($p = 0.026$). Participants in CCS, CNCS and CTL had a mean age of 22.40 years, 25.53 years and 24.60 years respectively. Although CCS participants were significantly younger than those in CNCS, when compared to CTL participants, the mean age difference was smaller and not significant.

CCS participants were heavier than those in CNCS ($p < 0.001$) and CTL ($p < 0.001$), and had a higher BMI when compared to those in CNCS ($p = 0.002$) and CTL ($p = 0.002$). This is not surprising given that CCS participants are Rugby players, hence, are expected to be of heavier build. Due to these significant differences, the results in Section 4.4 are presented with and without controlling the effects of age and BMI.

### Table 2: Sporting characteristics of the athletes (CCS and CNCS) groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>CCS (n = 15)</th>
<th>CNCS (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean sporting duration ± SD (year)</td>
<td>7.49 ± 2.66</td>
<td>5.98 ± 3.23</td>
</tr>
<tr>
<td>Mean self perceived sport competitive level-VAS ± SD (cm)</td>
<td>6.85 ± 1.64</td>
<td>6.68 ± 2.17</td>
</tr>
<tr>
<td>Mean self perceived sport contact level-VAS ± SD (cm)</td>
<td>8.77 ± 1.22</td>
<td>1.02 ± 2.10</td>
</tr>
</tbody>
</table>

SD = Standard Deviation; Self perceived sport competitive level-VAS = Self perceived sport competitive level-Visual Analog Scale; Self perceived sport contact level-VAS = Self perceived sport contact level-Visual Analog Scale

Table 2 shows the descriptive statistics for the sport participation duration, self perceived competitive-VAS of sports and self perceived level of contact-VAS between
participants in Group CCS and CNCS. CCS participants had a mean of 7.49 (2.66) years of participation (SD) in Rugby. CNCS participants had a mean of 5.98 (3.23) years of participation (SD) in track and field. CCS had a mean of 6.85 (1.64) cm and CNCS a mean of 6.68 (2.17) cm rating for the level of self perceived competitiveness-VAS (SD). The self perceived contact level-VAS (SD) score was 8.77 (1.22) cm for CCS and 1.02 (2.10) cm for those in CNCS.

Table 3: Self perceived pain tolerance level across the three groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>CCS (n = 14*)</th>
<th>CNCS (n = 15)</th>
<th>CLT (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean self perceived level of pain tolerance-VAS ± SD (cm)</td>
<td>5.74 ± 1.40</td>
<td>6.17 ± 1.35</td>
<td>5.23 ± 1.62</td>
</tr>
</tbody>
</table>

*One participant (from the 15 CCS participants) did not complete the self perceived pain tolerance-VAS score.

SD = Standard Deviation; Self perceived level of pain tolerance-VAS = Self perceived level of pain tolerance-Visual Analog Scale

Table 3 represents the rating of the participants’ self perceived pain tolerance level on the VAS. The mean self perceived pain tolerance-VAS (SD) for CCS was 5.74 (1.40) cm, CNCS was 6.17 (1.35) cm and CTL was 5.23 (1.62) cm. Although CNCS participants reported their self perceived pain tolerance to be the highest, there was no significant statistically differences between the three groups (p = 0.259).

4.3 ICC for Algometry and Pain-VAS across the three testing sessions

The intraclass correlation coefficient (ICC) was determined to indicate the amount of relative consistency and average agreement between the test and retest of the algometry and Pain-VAS techniques across the three testing sessions, with 1.00 indicating perfect reliability. The ICC for Pressure Pain Threshold (PPT) was 0.841, Pain-VAS for Pressure Pain Threshold (PPT Pain-VAS) was 0.901, Pressure Pain Tolerance (PPTO) was 0.896 and Pain-VAS for Pressure Pain Tolerance (PPTO Pain-VAS) was 0.926. Since the ICC of the PPT, PPT Pain-VAS, PPTO and PPTO Pain-
VAS were of high reliability, showing consistency across the three testing sessions; the mean scores of each variable are used for ANONA and Pearson Correlations analysis in the following sections of this paper.

4.4 Comparing mean pain threshold/tolerance across the three groups

Table 4: Mean Values of Algometry and Pain-VAS scores across the three groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>CCS (n = 15)</th>
<th>CNCS (n = 15)</th>
<th>CLT (n = 15)</th>
<th>All participants (n = 45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean PPT ± SD (kg/cm$^2$)</td>
<td>7.9 ± 1.7</td>
<td>7.1 ± 1.2</td>
<td>7.2 ± 2.1</td>
<td>7.4 ± 1.7</td>
</tr>
<tr>
<td>Mean PPT pain-VAS ± SD (mm)</td>
<td>53.0 ± 18.6</td>
<td>39.3 ± 16.6</td>
<td>47.9 ± 24.3</td>
<td>46.7 ± 20.5</td>
</tr>
<tr>
<td>Mean PPTO ± SD (kg/cm$^2$)</td>
<td>13.1 ± 2.7</td>
<td>14.8 ± 4.0</td>
<td>11.6 ± 3.5</td>
<td>13.2 ± 3.6</td>
</tr>
<tr>
<td>Mean PPTO pain-VAS ± SD (mm)</td>
<td>75.4 ± 10.7</td>
<td>82.2 ± 12.7</td>
<td>77.5 ± 20.4</td>
<td>78.4 ± 15.1</td>
</tr>
</tbody>
</table>

SD = Standard Deviation; PPT = Pressure Pain Threshold; PPT Pain-VAS = Pressure Pain Threshold Pain-Visual Analog Scale; PPTO = Pressure Pain Tolerance; PPTO Pain-VAS = Pressure Pain Tolerance Pain-Visual Analog Scale.

Table 4 shows the descriptive statistics of the mean pain threshold and mean pain tolerance in the three groups. For PPT Pain-VAS, CNCS reported lower subjective pain with a mean (SD) of 39.3(16.6) mm when compared to CCS, which had a mean (SD) of 53.0 (18.6) mm. For PPTO, CNCS tolerated most pressure with a mean (SD) value of 14.8(4.0) kg/cm$^2$. CCS tolerated a mean pressure (SD) of 13.1 (2.7) kg/cm$^2$ and CTL, a mean pressure (SD) of 11.6 (3.5) kg/cm$^2$. Conversely, CNCS, who tolerated more pressure pain, also reported higher pain rating on the VAS-PPTO, with the mean (SD) of 82.2 (12.7) mm. CCS had a mean (SD) of 75.4 (10.7) mm and CTL had a mean (SD) of 77.5 (20.4) mm.
Table 5: Correlation coefficient between measures of Algometry and Pain-VAS scores (Unadjusted and Adjusted for Age and BMI)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Unadjusted</th>
<th>Adjusted**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
</tr>
<tr>
<td>Mean PPT (kg/cm²)</td>
<td>0.914</td>
<td>0.409</td>
</tr>
<tr>
<td>Mean PPT pain-VAS (mm)</td>
<td>1.784</td>
<td>0.181</td>
</tr>
<tr>
<td>Mean PPTO (kg/cm²)</td>
<td>3.097</td>
<td>0.056</td>
</tr>
<tr>
<td>Mean PPTO pain-VAS (mm)</td>
<td>0.785</td>
<td>0.463</td>
</tr>
</tbody>
</table>

*: significant at p<0.05

** Model adjusted for Age and Body Mass Index (BMI)

PPT = Pressure Pain Threshold; PPT Pain-VAS = Pressure Pain Threshold Pain Visual Analog Scale; PPTO = Pressure Pain Tolerance; PPTO Pain-VAS = Pressure Pain Tolerance Pain Visual Analog Scale

Table 5 shows the ANOVA analysis of mean PPT and mean PPTO in the three groups. There is a borderline significance in mean PPTO across the three groups (p = 0.056). Post-hoc Tukey test showed that participants in CNCS had a significantly higher mean PPTO when compared to those in CTL (p = 0.044), but no difference between the CCS and CNCS participants. There was also no difference in the PPTO Pain-VAS, PPT and PPT Pain-VAS.

Since the three groups were significantly different in age, weight and BMI, analyses were repeated by adjusting the potential confounding factors of age and BMI using the Analyses of Covariance (ANCOVA). There was a significant difference in mean PPTO among the three groups after the adjustment (p = 0.016), but there was no significant difference in mean PPT (p = 0.420), mean PPT Pain-VAS (p = 0.232) and mean PPTO Pain-VAS (p = 0.086). Post-hoc analyses showed that participants in CNCS had significantly greater pain tolerance when compared to those in CTL (p = 0.008) but there was no significant difference in terms of pain tolerance between CCS and CNCS.
4.5 **Correlation between Pain-VAS and Algometry**

Pearson Correlation of Pain-VAS and algometry reading across the three groups showed that there was a low but significant correlation between PPT and PPT Pain-VAS ($r = 0.376, p = 0.011$). As for pressure pain tolerance, there was no correlation between PPTO and PPTO Pain-VAS. Participants with higher PPT were also shown to be positively correlated to having higher PPTO ($r = 0.537, p = 0.000$).

4.6 **Correlation between Self perceived sport competitive level-VAS, Algometry and Pain-VAS techniques**

Correlation analysis of self perceived competitive level-VAS for the CCS using Pearson Coefficients showed a borderline correlation ($r = 0.513, p = 0.051$) between the self perceived competitive level-VAS and mean PPT.

4.7 **Correlation between Self perceived pain tolerance level-VAS, Algometry and Pain-VAS**

Pearson Correlation of self perceived pain tolerance level-VAS across the three groups showed a significant correlation between self perceived pain tolerance level-VAS and mean PPT for all three groups (see table 6). In addition, there was a significant correlation between self perceived pain tolerance level-VAS and PPT Pain-VAS for CTL.

**Table 6: Result of Pearson correlation with self perceived pain tolerance level-VAS as variable in Algometry and Pain-VAS techniques**

<table>
<thead>
<tr>
<th>Variables</th>
<th>CCS (n = 14)</th>
<th></th>
<th>CNCS (n = 15)</th>
<th></th>
<th>CLT (n = 15)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>p</td>
<td>r</td>
<td>p</td>
<td>r</td>
<td>p</td>
</tr>
<tr>
<td>Mean PPT (kg/cm²)</td>
<td>0.690</td>
<td>0.006*</td>
<td>0.555</td>
<td>0.032*</td>
<td>0.603</td>
<td>0.017*</td>
</tr>
<tr>
<td>PPT pain-VAS (mm)</td>
<td>-0.27</td>
<td>0.928</td>
<td>0.49</td>
<td>0.863</td>
<td>0.541</td>
<td>0.037*</td>
</tr>
</tbody>
</table>

* : significant at p<0.05

PPT = Pressure Pain Threshold; PPT Pain-VAS = Pressure Pain Threshold Pain-Visual Analog Scale
4.8 Summary

Results from the analyses indicated that the research hypotheses were rejected – this study showed that contact sport athletes do not tolerate more experimental pressure pain as compared to the non-contact sport athletes. ANOVA showed that there was no significant pain tolerance and threshold difference between the two groups of athletes. However, both groups of athletes have more pain tolerance than the non-athletes. Interestingly, when compared to the non-athlete (control) participants, only non-contact sport athletes showed a significant tolerance to pressure pain.

The pressure algometry and Pain-VAS techniques both showed high ICC when tested across the three testing sessions. Both instruments hence are reliable tools for this experimental pressure pain study and give consistent results across time. When comparing the variables from both techniques, pressure pain threshold is correlated to the Pain-VAS score. Self perceived pain tolerance VAS also showed a correlation to pressure pain threshold. It suggests that pressure pain threshold might play an important role in the understanding of pain perception in athletes.
Chapter 5: Discussion

5.1 Introduction

In this last chapter, the results of the study are discussed. Limitations of the current study as well as recommendations for future studies are also presented.

5.2 Discussion

5.2.1 Descriptive Statistics

When examining the participants’ descriptive statistics across the three groups, there were differences in age and BMI. The contact sport athletes (CCS), who are Rugby players, were considerably younger and had a larger BMI when compared to the other two groups.

Age and BMI

Generally, age and BMI were shown to have no significant correlation to the participants’ level of pain threshold and tolerance. However, as CCS participants showed significant differences in the variables of age and BMI, Pearson correlation analysis was performed on them. It showed that individually, CCS participants’ age was negatively correlated to pain threshold ($r = -0.566, p = 0.028$). In other words, pain threshold decreases as age increases, i.e. the younger the contact sport athlete, the more pain threshold he has.

Although human and animal studies that have tried to clarify the hypothesis of possible changes of experimental pain sensitivity with age have not given a clear-cut answer to this issue so far (Pickering et al., 2002; Chakour et al., 1996), few studies have specifically found that pain threshold decreases with age (Lautenbacher et al., 2005). For example, Pickering et al. (2002) concluded from their study on 21 younger
male adults (mean ± SD age of 22 ± 2 years of age) when compared to 21 elderly men (mean ± SD age of 74 ± 3 years of age) that the younger male had higher pressure pain threshold and that pain threshold decreased as age increased. The mean age from Pickering et al. study (2002) is similar to the mean age of CCS (mean ± SD age of 22.4 ± 1.2 years of age) in this study. This gives some support to the fact that young adults do have higher pain threshold. Participants from the non-contact sport and non-athlete groups, although older than CCS participants, were in the age range of 25.5 years old and 24.6 years old respectively, unlike the huge age difference between the young adults and elderly men in Pickering et al. (2002) study. No studies have been found to suggest that the difference in the few years of age in these young adult groups will result in having different pain threshold. Studies could be performed further to examine the different age ranges in the younger age group (e.g. young children, teenagers and young adults) to check on the changes in their pain threshold.

This study also showed that BMI in CCS participants was negatively correlated to the self perceived pain tolerance level, i.e. the heavier participants perceived themselves to have less pain tolerance. This has not been shown in any other studies. Perhaps, based on the cross sectional analysis study by Stovitz et al. (2008) which states that obese adolescents have a positive correlation to higher musculoskeletal pain, one could hypothesise that participants with higher BMI might have less tolerance to pain due to higher possibility of existing pain. More studies in this area are warranted.

It must be pointed out that the “Visual Analog Scale” (VAS) score for self perceived pain tolerance (self perceived pain tolerance-VAS) used in this study has not been validated. Better tool like the “Sports Inventory for Pain” (SIP; Meyers et al., 1992 (a)) could be deployed for further examination on this psychological factor. The SIP (Meyers et al., 1992 (a)) is a 25-item sport specific instrument that measures five
subscales (coping, cognitive, catastrophising, avoidance and body awareness), relevant to competition. The SIP has provided a reliable and predictive indicator of pain-induced psychological distress and subsequent physical response. Adequate internal consistency (alpha = .61 to .88), test-retest reliability ($r = .69$ to $.86$) and low social desirability ($r = -.28$ to -.13) have been well established in a number of sport populations (Meyers et al., 1992 (a) (b)). However, the aim of this study was not to examine the psychological domain of pain in athletes, hence, the self perceived pain tolerance-VAS was chosen as a simple tool to test if those athletes, who think they have higher pain tolerance, will have a higher pain tolerance scale on the algometry accordingly.

Across the three groups, based on their interpretation of the self perceived pain tolerance-VAS, CNCS participants felt that they could tolerate pain the most. However, it was noted that there was no significant difference across the three groups. Only the level of self perceived pain tolerance was found to have significant correlation to the pain threshold across the three groups. This might imply that self perceived pain tolerance-VAS technique can be used to assess pain threshold level, which in turn suggests a co-relationship to pain tolerance level in this current study.

5.2.2 Pain Threshold and Tolerance

Results in this study showed that athletes from the CNCS group had a significant higher pressure pain tolerance than non-athletes. This is in line with other studies (Sullivian et al., 2000; Ahern & Lohr, 1997; Hamilton et al., 1989) which suggested that athletes have higher pain tolerance than non-athletes.

There is also a correlation of pain threshold to pain tolerance level, especially obvious in the CNCS participants. This suggests that having a higher pain threshold (i.e. bias towards physiological factor) does improve the pain tolerance level (i.e. bias
towards a combination of physiological and psychological factors) for this group of athletes.

This study also showed that contact sport participants did not have more pressure pain tolerance and threshold when compared to non-contact sport athletes. This is in contrast to the common belief that contact sport athletes have higher pain tolerance (Ryan & Kovacic, 1966). Since there is no other similar study comparing pain tolerance in these two groups of athletes, discussion could only be limited to Ryan and Kovacic (1966) study.

5.2.2.1 Method of the Pressure Pain Application

Ryan and Kovacic (1966) used the sphygmomanometer cuff to induce pressure pain on their participants. The sphygmomanometer cuff is widely used in medicine for indirect arterial pressure measurement and for tourniquet applications in surgery. Although the cuff pressure measures the intra-arterial pressure under the cuff (Ernst et al., 1986; Van Egmond et al., 1985), there is no study to validate the usage of the sphygmomanometer cuff as a pressure pain applicator. Besides inducing pressure pain, the sphygmomanometer also induces ischemia pressure on the calf muscles. This might cause disturbance to the subjects’ perception of the pressure pain, and thereby, decreasing the specificity of the pressure pain test. Hence the results of the Ryan and Kovacic (1966) might not be reliable due to the poor validity of the pain inducer used.

This current study used the algometry technique to induce pressure pain on the participants’ tibia. The reliability and validity of the algometry had been discussed in the previous chapters – Solomon et al. (2003) used a handheld pressure algometer to repetitively induce pressure pain on the tibial shaft of 180 healthy volunteers to study the effects of co-administration of several physical modalities on pain control. Their
study showed consistent results with repeated testing. This current study also showed good Intraclass Correlation (ICC) for the algometry technique. This indicates that the pressure algometer can be regarded as a reliable method for the study of mechanical pain threshold.

5.2.2.2 Types of Sports and Athletes

The athletes participating in Ryan and Kovacic (1966) study were of different groups of contact (i.e. football, boxing and wrestling) and non-contact (i.e. golf and tennis) sports. The results from their study might not be comparative as the sports are of different strenuous physical level. For example, golfing is not as physically strenuous as compared to tennis in its own classification of non-contact sports. And in comparison to contact sport types, golfing is far less physically strenuous. This might have an influence in having a higher pain tolerance for the contact sport athletes whose sport types are supposedly more physically strenuous in nature, through the “Exercise Induced Analgesia” (EIA) effect. This current study used athletes of similar physical strenuous level which theoretically eliminates this factor of physiological difference from exercising.

Ryan and Kovacic (1966) used a wider range of contact sport athletes whereas in this study, only Rugby players were used. Contact sport athletes, being subjected to physical insults to their bodies through the nature of their harsh physical training and competition requirements, will develop more tolerance to pain as these conditions carry with it the experience of sub-maximal pain (Broucek & Bartholomew, 1993). However, different contact sports might induce different levels of insult which results in different pain tolerance. For example, when compared to football, martial art would induce more changes in pain perception due to the direct contact involved in the sport. Focht,
Bouchard and Murphey (1998) were able to give evidence that through martial art training, there was an elevation in pressure pain threshold and decrease in pain rating. Following 14 weeks of martial arts participation, novice participants showed a significant change in pressure pain threshold and pain tolerance. The repetitive physical contacts associated with the controlled kicking, punching, blocking and sparring may result in the novice participants to experience less pain. Till today, there are no other studies which examine the effect of different contact sport types on pain tolerance.

The factor of being competitive could also shed some light to the difference in the results of this current study to the Ryan and Kovacic (1966) study. The athletes used in their study were only actively involved in their sports during high school or college. In other words, they were not active athletes at the point of the study. Hence, results from this group of participants might not be comparable to the actively competitive athletes such as the ones in this study. The athletes used in this study are all still actively competing at sports clubs and university sports events.

Both groups of “active” athletes in this study rated similar level of competitiveness within their sport types on the “Self perceived competitiveness Visual Analog Scale” (self perceived competitiveness-VAS), at a moderate competitiveness level. In Ryan and Kovacic (1966) study, the “inactive” athletes were not asked to rate their previous competitiveness levels when they were involved in their sports. Perhaps, the different levels of these athletes’ competitiveness could be a reason why the contact sport participants have more pressure pain tolerance than the non-contact sport athletes in Ryan and Kovacic (1966) study.

Ryan and Kovacic (1966), and this current study used non-elite athletes. Could higher professional athletic level result in different pain perception then? Encarnacion et al. (2000) study, to quantify pain coping styles of 135 ballet dancers and to investigate
possible differences in regard to skill level and gender, showed that, although not statistically significant, pain coping differences were evident, especially between professional and academy ballet performers. Higher-skilled professionals were shown to exhibit lower coping and cognitive scores than less skilled or novice academy performers. This was in agreement with prior research, reporting similar responses among elite and sub-elite college rodeo athletes (Meyer et al., 1992(a)). In contrast, competitive runners when compared to recreational runners have higher coping and cognitive scores to pain perception (Reed, Bourgeois & LeUnes, 1994). This finding supports the result in the current study where the non-contact sport athletes (track and field runners) reported higher self perceived pain tolerance than the other two groups.

Ryan and Kovacic (1966) did not report the age of the participants besides citing that they were university students. The participants in this current study had a mean ± SD age of 24.1(3.3) years old. Although younger athletes from this study was found to have higher pain threshold (i.e. relating to physiology of pain), studies cited that younger or adolescent athletes were found to have less pain perception (i.e. relating to physiology and psychology of pain). For instance, Tripp et al. (2003) found that adolescent athletes reported greater pain related helplessness and rumination than adult athletes due to the factor of catastrophising after post orthopaedics operation. Greater catastrophising in adolescents may be influenced by their relative lack of understanding about the nature of their injury, their lack of experience with recovery from injury and the potential threat to the loss of competitive status. The contact sport participants in this current study were significantly younger than the non-contact sport participants. This might explain why there was no difference in pain tolerance between the two groups of athletes – younger athletes have lower pain perception as suggested by Tripp
et al. (2003), although they were supposedly exposed to more contacts due to their sport type.

5.2.2.3 Methodology and Power of Study

In Ryan and Kovacic (1966) study, only two sessions were devoted to testing. The first session was used to measure pain threshold while the second measured pain tolerance. Hence, the result on pain tolerance provided by Ryan and Kovacic (1966) was merely based on one test. This questions the reliability of the data from their study, given the method of pain applicator was not well studied upon as well. As for this current study, the reliability of the data was enhanced with three repeated testing which was showed to have high ICC across the sessions. Due to the repeated testing, control subjects, i.e. the non-athletes, were used to control the effects of repeated testing and therefore eliminate the confounding effect of analgesia associated with the pain assessment (Padawer & Levine, 1992).

The power of Ryan and Kovacic (1966) study was also questionable. Their study consisted of a subject size of 60 (3 groups of 20 subjects each) and 11 subjects did not turn up for the second testing (for the pain tolerance session). It is likely to affect the statistical power of the study. This current study has a total subject size of 45 participants (3 groups of 15 subjects each) which Portney and Watkins (2000) considered as an acceptable statistical power for this research design. All subjects completed the testing in this research study.

5.2.3 Pain-VAS and Algometry

In this study, correlation analysis on the Pain-VAS and algometry data showed a low positive correlation of pain threshold-VAS to pain threshold reading on the
algometry. Hence, when the threshold reading on the algometer is high, the subjective report of the pain-VAS level goes up too. However, this result was not supported by Waling et al. (2001) study. In their study, they compared the variability of muscle pain measured as subjective pain threshold ratings in 24 women with trapezius myalgia, with special focus on variability due to time of day and day of week. Their study found no correlation between VAS ratings and pain threshold readings. There were also large fluctuations in the VAS ratings but not in threshold readings.

It is, however, important to note that the subjects were females and had existing pain in Waling et al. (2001) study. The participants in this current study were males and had no pain during the test. For the effect of sex, Berkley (1997) stated that inductive analysis of available literature indicates that for experimentally induced acute somatic (usually skin) stimulation, females often have lower thresholds, greater ability to discriminate, higher pain ratings and less tolerance to noxious stimulus than males. However, these differences are inconsistently observed, relatively minor, existed only for certain forms of stimulation and can be affected by numerous situation variables in daily life such as the presence of disease, the setting of the experiment, the characteristics of the experimenter and even nutritive status. For the effect of existing pain, Giesbrecht and Battie (2005) also found in their study that subjects with chronic lower back pain and at combined sites related to the lumbar spine had a lower global pressure pain threshold and tolerance. This suggests that subjects with chronic pain will exhibit lower pressure pain tolerance due to the possibility of tissue peripheral sensitisation (Wright, 1999).
5.3 Limitations and Recommendations for Future Research

5.3.1 Limitations

1. The major limitation of most of the pain induction techniques is that they are inherently safe and individuals know that the induced pain can be terminated at any time (Pen and Fisher, 1994). Participants might be aware that they are unlikely to suffer tissue damage and they can withdraw from participation at any one time (Milling, Kirsh, Meunier & Levine, 2002). Thus it is possible that pain tolerance and performance levels are higher in experimental settings than in real-life situations. This might not be translated to on field injury events when athletes might not tolerate the same intensity of pain.

Participants’ perception to the pain stimulus has a bearing on the outcome of pain induction studies. Jackson et al. (2005) examined the impact of threatening information on coping and pain tolerance in healthy adult sample. Prior to engaging in a cold pressure test, 121 college students were randomly assigned to one of three conditions; a threat condition, a reassurance condition and a control condition about the “possible” damage of the cold pressure. Their experiment showed that appraisals of threat have an influence on tolerance level for cold pressure pain and use of specific pain coping strategies. Participants warned with potentially threatening information were less likely to tolerate when compared to those reassured of their safety. In this current study, participants were assured that the pain induced is safe and not damaging.
2. Weiss (2003) commented that limitation in most pain research studies is the sample size and the heterogeneous variability often translates to non significant statistical difference between age groups. A larger sample size might show a significant difference in pain tolerance between the two athletic groups.

3. In this current study, pressure pain algometry, established for its reliability and validity, was the only pain applicator used. Lautenbacher et al. (2005) commented that a single experimental pain induction method does not allow comparisons within the same study, e.g. comparison of pain induction techniques within the same group of subjects. Ryan and Kovacic (1966) used radiant heat for pain induction for pain threshold testing, a gross pressure cuff with a foot ball cleat attached to induce mechanical pressure pain and a pressure cuff to induce muscle ischemic pain. Different stimulus will yield different responses from athletes as they stimulate different types of pain system as discussed in Chapter 2. For instance, Janal et al. (1994)’s study on runners and control subjects indicated that runners are insensitive to specific noxious stimulations, less sensitive to noxious cold when tested with cold pressure, than controls, but not so for thermal pain and ischemic pain tests.

5.3.2 Recommendations for Future Research

1. The current study showed that athletes’ self perceived pain tolerance-VAS rating has a correlation to pain threshold on the algometry, and the latter corresponds positively to the pain tolerance level. It would be good
to validate the self perceived pain tolerance-VAS against the Sports Inventory for Pain (SIP) in similar study like the current one. Straub et al. (2003) had used the SIP to study the pain apperception of contact and non-contact sport athletes. However, their study was non-experimental and had certain limitations of not being able to assess the physiological differences. The pressure algometry, which assesses more towards the physiological aspects of pain, if used in combination with the SIP might give a more complete understanding of the physiological, psychological and mental aspects of athletes’ perception to pain. And if the self perceived pain tolerance-VAS is validated, it will be an easier tool to use as compared to the SIP.

2. The electronic algometer was developed by Jensen et al. (1986) to improve the manual algometer technique and minimise any confounding factors which the manual algometer has, like speed, constancy of pressure and time lap in verbal communication between the participants and examiner. Further study can use the electronic algometer instead of the manual algometer.

3. Experimental pain and clinical pain are substantially different phenomena. Clinical pain, whether acute or chronic, is usually intense, unavoidable and unpredictable. In contrast, experimental pain is typically mild in intensity and brief in duration. Not only will the stressor be terminated, but the pain experienced will also decline because the pain is due to the stimulation. Pen and Fisher (1994) suggested using exercise induced muscle soreness as one of the pain induction techniques to alleviate this limitation and therefore, to provide more realistic pain
tolerance levels. This experimentally induced pain technique might be the closest feel to real time injury.

4. Since age is one of the significant variables in this study, future studies could recruit a wider age group of 15 years old to 25 years old to examine if age will have an effect on pain tolerance level. It has been suggested from the developmental psychology that athletes of different age group employ different coping strategies for pain management. For example, early and middle adolescents reply upon parents and classmates as the significant source of social support and for physical competence information. Older adolescents are more likely to use self-referenced sources (e.g. self-improvement) of physical competence information and peers as social support and motivation (Garofalo et al., 2006). This might show more difference in the pain tolerance level which has a larger bearing on the psychology of pain perception.

5. Since this current study used only athletes of moderate competitiveness level, further study should be done to examine elite or professional athletes and of different contact and non-contact sports to establish if the specificity of sports could influence pain perception in athletes. No studies have been found on this aspect as yet.

5.4 Conclusion

This current study showed that athletes have higher pain tolerance than non-athletes, although not significantly different when comparing contact sport athletes to non-athletes. It was not able to show that contact sport athletes have higher pressure pain tolerance than non-contact sport athletes. This suggests that both groups of athletes
in this study have similar pain perception and hence, have important implications. Pain is a multifactor experience that is complex. Understanding this relationship in athletes is paramount for the development of appropriate intervention and coping techniques in treatment of sport injury.

Most athletes at some point of their career will experience some form of injuries, either minor or major. Sport psychologists describe pain as the most pervasive and debilitating barrier to rehabilitation and recovery (Heil, 1993) from sport injuries. The athletes’ attitudes towards pain and the cognitive strategies they use while experiencing pain may be reflected in their pain tolerance levels and their performance as well as adherence to sport injury rehabilitation (Pen & Fisher, 1994). Byerly et al. (1994) and Fields et al. (1995) found those individuals, who are able to tolerate pain better, tend to adhere more rigidly to their rehabilitation programme. Till date, there is no available information to differentiate the sports rehabilitation adherence between the contact and non-contact sport athletes. Since both groups of athletes had shown similar pain tolerance level in this study, it could be postulated that there might be no differences in their adherence to sports rehabilitation. However, more research data is required to support this postulation. If data is found not to be true (i.e. contact sport athletes might perform better or poorer), it will be interesting to then examine the reason(s) behind it.

Both contact and non-contact sport athletes have showed higher pain tolerance when compared to the non-athletes. Levy et al., 2006 studied 70 patients (31% of them competitive athletes and 69% recreational athletes) on the determinants of adherence to sport injury rehabilitation found that there is a direct relationship to patients having more mental toughness to better subjective pain self report. Individuals who are more mentally tough perceive their injury to be less threatening and less susceptible to further injury than their less mentally tough counterparts. Crust and Clough (2005) in their
study also found mental toughness to be related with physical endurance and better coping strategies that enable them to ignore pain. Hence to facilitate rehabilitation, it may be beneficial to improve mental toughness or pain tolerance as they have a direct relationship. In this aspect, if there is a way to improve the pain tolerance of the non-athlete population, there will be a chance to enhance their rehabilitation adherence and outcome.

With respect to pain, there is a possibility that this characteristic may have a negative influence on rehabilitation adherence and recovery outcomes. This may be due to individuals appraising their injury to be less severe and less susceptible to reoccur and thereby perceive compliance to clinic based activity to be less important. This, in turn, suggests that if athletes have higher pain control, it might worsen injury as they report less. Sternberg et al. (1998) also supported this notion as they found out that self report of pain during athletic competition may not always be indicative of the true nature of injury. Unnecessary tissue damage may result from failure to attend to a potentially painful injury sustained during competition. Contact sport athletes might report less pain due to the high expectation that they are supposed to have more pain tolerance. This study proves that this notion is not true. Hence, if this stigma could be removed from this group of athletes, they might then report their pain truthfully in the future.

Besides the athletes themselves, professionals’ perception of athletes’ pain is also important. For example, clinicians have this perception that athletes have higher pain perception, especially the contact sport athletes. This might affect their management on this group of athletes and cause more harm to them. Bucknall, Manias & Botti (2001) found that the effect of “expected norms” relating to pain management practices may subtly encourage patients to conform to nurses’ preconceptions, therefore
preventing an individualised approach to care, e.g. patients who did not conform to health professionals’ expectations were perceived to be manipulative. Thus, athletes, especially those involve in contact sports, might conform to the notion that they are expected to tolerate more pain and resulted in them not getting proper treatment and health care management.

On the other hand, if having lesser sensitivity to pain would help to explain athletes’ ability to maintain rigorous training schedule or support seemingly maladaptive behaviours, such as running with stress fractures or during heart attacks, information about pain sensitivity in regular exercisers would not only help to explain their apparent pain tolerant behaviours but could also help to explain why some people, who are less pain tolerant find it difficult to maintain regular exercise programmes (Janal et al., 1994). If this group of people can improve their pain tolerance, there might be a chance of improving their adherence to regular exercises. One approach could be via martial art training, which Focht, Bouchard & Murphey (1998) had found to improve pain tolerance in normal subjects. Conversely, such specific sport can be prescribed to athletes (both contact and non-contact) to improve pain tolerance and hence better their sports performance.

In conclusion, this current study does not support the concept that contact sport athletes have higher pain perception to non-contact sport athletes. From current knowledge, this study could be the second experiment examining pain perception between contact and non-contact sport athletes, since the first one by Ryan and Kovacic in 1966. More studies, looking at the various different contact and non-contact sport types, are warranted to build up larger evidence based knowledge in this area.
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Appendix 1: Letter of Invitation for Research Participation

Date:

Dear

Re: Pain threshold and tolerance research in athletes

Please allow me to introduce myself. My name is Ng Chong Ching, a master degree student with the National Institute of Education, Singapore. For my master’s degree research, I am examining the difference in experimental induced mechanical pain threshold and tolerance between competitive males contact and non-contact sport athletes. The participants will be subjected to mechanical pressure pain, which is painful but non-harmful. Participation will be on a voluntarily basis.

I hereby would like to invite your club/school’s athletes to participate in this research. I seek your kind assistant to disseminate this information to your athletes.

Please refer to the attached information sheet for more detail.

If you have any queries, please contact me at my HP: 98369105 or email: manualcircle@gmail.com . Thank you.

Yours sincerely,

Ng Chong Ching
(Physiotherapist)
Master (Manual Ther),
Grad Cert In Ortho Manip Ther,
Bsc (Physiotherapy),
Dip (Biotechnology)
Appendix 1.1: Participants’ Information Sheet

Participants’ Information Sheet

Dear potential participants,

Thank you for taking interest in my research project, which examine the difference in pain threshold and tolerance level between competitive contact and non-contact sport athletes. Your participation will allow professionals like sport doctors and physiotherapists to better manage sports injuries and its rehabilitation.

For this study, you will be subjected to a painful but non-harmful stimuli. You are allowed to stop the experiments at any point of time. Your participation will be voluntarily. You will be expected to return on 3 separate occasions for testing.

To be included in this study, you must be:

1. Currently a competitive contact or non contact sport male athlete (competing more than 2 years in the same competitive sports) or a non-athletic male.
2. Age group between 21 years old to 35 years old on the date of recruitment.
3. Healthy and not diagnosed with any medical condition that might affect your pain perception or tolerance.

However, if you were unsure of your known medical condition, you would contact me for clarification. All information provided will be treated with confidentiality.

Please contact me at my Hp: 98369105 or email at manualcircle@gmail.com if you are interested to participate or want to find out more about this study. I look forward to your participation. Thank you.

Yours Sincerely,

Ng Chong Ching (Physiotherapist), NIE post-graduate student
Appendix 2: Advertisement Poster

Are you “man”?

How much pain can you take?

Come on down and be a *participant for this research!

Find out for yourself how “man” you are.

*Ladies just don’t get it.

Call me at Hp 98369105 or drop me an email: manualcircle@gmail.com for more information or participation.

Ng Chong Ching

(Post graduate student, NIE, PESS)
### Appendix 3: Classification of Sports (Dyment et al., 2001)

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<th>Limited contact/impact:</th>
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Appendix 4: Approval from NIE, PESS

PHYSICAL EDUCATION & SPORTS SCIENCE ACADEMIC GROUP

Date: 8\textsuperscript{th} Feb, 2006

Applicant: Ng Chong Ching
Through Supervisor: A/P Michael Koh

Dear Chong Ching,

Ethical Review for "Differences in pressure pain threshold and tolerance between two athletic types (rugby and track and field)"

Thank you for your application to the Ethical Review Board of the Research and Graduate Studies Committee of PESS.

After colloquium review of your application to conduct research involving human subjects, I am pleased to convey to you that the Review Board has approved your project as outlined in your stated research proposal. May I also remind you that if there are any changes to the procedures involving human subjects, you must make amendments and resubmit these changes to the committee.

Your research Ethics Approval Code is 826. Please quote this number in future references as and where necessary.

Best wishes for your research.

Mike McNeill
PESS Research and Graduate Programme Coordinator

cc: Head PESS
DATED THIS 23 OF AUGUST 2006

Ng Chong Ching
("Researcher")

And

Singapore Physiotherapy Association
("Grantor")

RESEARCH FUNDING AGREEMENT

DAVID LIM & PARTNERS
Advocates & Solicitors
50 Raffles Place #17-01
Singapore Land Tower
Singapore 048623
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THIS AGREEMENT is made on the 2nd day of August 2006

BETWEEN:

(1) Ng Chong Ching (NRIC No. [redacted]) of Blk 655C Toa Payoh Central (the "Researcher"); and

(2) Singapore Physiotherapy Association Trust Fund (the "Grantor") (ROS NO 52/63 TAP) of Physiotherapy Department, Singapore General Hospital, Outram Road, Singapore 169608

WHEREAS

(A) The Researcher is desirous of conducting a study in accordance with the Gantt Chart as hereinafter defined; and

(B) The Grantor has agreed to grant to the Researcher up to the maximum amount of Singapore Dollars Seven Thousand One Hundred and Twenty-five (S$7,125) for the Researcher to carry out the research in accordance with the Gantt Chart upon the terms and conditions hereinafter set out.

NOW, THEREFORE IT IS AGREED as follows:-

1. DEFINITIONS AND INTERPRETATION

1.1 In this Agreement, except to the extent that the context requires otherwise:-

"Advance Date" or "Advance Dates" shall mean the date or dates on which the Grant is advanced;

"Gantt Chart" means the comprehensive research plan agreed to by the Researcher and the Grantor substantially in the form as attached in Schedule 1 of this Agreement;

"Grant" means the amount of money to be distributed in accordance with Clause 4;

"Host Institution" means the National Institute of Education;

"Maximum Grant" means the maximum grant of S$7,125 to be advanced by the Grantor under this Agreement;

"Research" means any research carried under, in connection with, or contemplated under the Gantt Chart or under this Agreement;

"Singapore Dollar(s)", "$" and "S" mean the lawful currency of Singapore;

"Transaction" includes any transaction, act, event or omission of whatever nature; and

"SPA" means the Singapore Physiotherapy Association.

1.2 Any reference in this Agreement to a statutory provision shall include that provision and any regulations made in pursuance thereof as from time to time modified or re-enacted, whether before or after the date of this Agreement, so far as such modification or re-enactment applies or is capable of applying to any
Transactions entered into and (so far as liability thereunder may exist or can arise) shall include also any past statutory provision or regulation (as from time to time modified or re-enacted) which such provision or regulation has directly or indirectly replaced.

1.3 (a) The headings in this Agreement are inserted for convenience only and shall not affect the construction of this Agreement.

(b) Any reference in this Agreement to "this Agreement" includes all amendments, additions, and variations thereto agreed between the parties hereto.

(c) Unless the context otherwise requires, words importing the singular shall include the plural and vice versa; words importing a specific gender shall include the other genders (male, female or neuter), and 'person' shall include an individual, corporation, company, partnership, firm, trustee, trust, executor, administrator or other legal personal representative, unincorporated association, joint venture, syndicate or other business enterprise, any governmental, administrative or regulatory authority or agency (notwithstanding that "person" may be sometimes used herein in conjunction with some of such words), and their respective successors, legal personal representatives and assigns, as the case may be, and pronouns shall have a similarly extended meaning.

(d) A reference to a "month" is a reference to a period starting on one day in a calendar month and ending on the numerically corresponding day in the next succeeding calendar month.

2. THE GRANT

The Grantor shall extend to the Researcher grants up to the Maximum Grant of S$7,125 upon the terms and subject to the conditions of this Agreement.

3. CONDITIONS PRECEDENT

3.1 Subject to the provisions of this Agreement, the Grant will be advanced by the Grantor to the Researcher at his request if the following conditions are fulfilled:

(a) all representations and warranties in Clause 5 have been complied with and would be correct in all respects if repeated on each Advance Date by reference to the circumstances then existing; and

(b) all research plans, Gantt charts and such other documentation as required by the Grantor in relation to the Research have been provided to the Grantor to its satisfaction.

4. DISBURSEMENT AND SALARIES

4.1 The Grantor shall disburse an Initial Grant of S$2,500 at the time of execution of this Agreement.

4.2 Subsequent disbursements of the Grant shall be made every three (3) months commencing three (3) months from the date of this Agreement up to the Maximum Grant, to compensate and reimburse the Researcher for his time in conducting the study and his equipment costs, always provided that:
(a) the Researcher submits time-sheets and such other evidence of work to
the Grantor at least three (3) weeks before the Advance Date;

(b) the Researcher submits original receipts for equipment and other materials
used in the conduct of his research at least three (3) weeks before the
Advance Date; and

(c) the Grantor, in its sole discretion, is satisfied that such evidence of work
and receipts are in accordance with the agreed research plan in the Gantt
Chart.

5. REPRESENTATIONS AND WARRANTIES

5.1 The Researcher represents and warrants to and for the benefit of the Grantor that
he:

(a) has the power to enter into and perform his obligations under this
Agreement;

(b) is not in breach of any agreement or undertaking as a result of entering
into this Agreement, including but not limited to his obligations under any
agreement with the Host Institution;

(c) has the skills, facilities and capacity necessary to perform the Research
under this Agreement; and

(d) will at all times during the duration of this Agreement be a member of the
SPA.

6. OBLIGATIONS OF RESEARCHER

6.1 The Researcher shall carry out and do all such related work in accordance with
the research plan under the Gantt Chart.

6.2 In the event of any delay or non-compliance with the Gantt Chart, the Researcher
shall inform the Grantor of such delay and/or non-compliance as soon as
reasonably practicable, and to discuss any change to the research plan under the
Gantt Chart with the Grantor, such change to be approved at the Grantor's sole
discretion.

6.3 The Researcher shall provide the Grantor with summary reports on the progress
of the Research together with the time-sheets in accordance with the schedule
set out in the Gantt Chart. The Researcher further agrees to provide the Grantor
with further information relating to the Research upon the request of the Grantor
at any time.

6.4 The Researcher agrees that the final findings of the Research shall first be
disclosed solely to the Grantor in written form, and shall not be published,
presented, communicated or otherwise disseminated to any other person for a
period of 30 days from the date of disclosure to the Grantor ("First Disclosure").

6.5 The Researcher further agrees that, subsequent to the 30 days from the First
Disclosure, he may, publish, present, communicate or otherwise disseminate the
contents and results of the Research, subject to the following:-

5
(i) the Researcher shall first inform the Grantor of the details of the proposed publication, presentation, or communication, including but not limited to: the name of the publication, the contact person thereof, telephone and facsimile numbers and address of the publication, and/or the place and mode of presentation; and

(ii) the Researcher shall acknowledge the funding of the Research by the Grantor in his presentations, publications or communications, and, in the case of a written publication or communication, in clearly legible wording in a prominent place.

6.6 The Researcher shall conduct the research professionally and ethically, in particular, with regard and in accordance with the code of ethics approved by the Host Institution ("Code of Ethics"), a copy of which has been provided to him.

7. OBLIGATIONS OF GRANTOR

7.1 For the avoidance of doubt, the Grantor is under no obligation to provide any assets, materials, funds, guidance, assistance or any benefit of any kind whatsoever to the Researcher apart from the disbursement of the Grant in accordance with the terms of this Agreement.

8. TERMINATION

8.1 Events of Termination

This Agreement shall ipso facto terminate, and all moneys advanced under this Agreement shall become due and payable to the Grantor, upon the occurrence of any of the following events:

(a) the Researcher ceases to be a member of the SPA;

(b) the Researcher’s death, bankruptcy or mental unsoundness;

(c) the Researcher is convicted of a criminal offence;

(d) the Researcher is unwilling or unable to comply with his obligations under clause 6 of this agreement; or

(e) the Researcher is found to have breached the Code of Ethics.

8.2 Termination by Grantor

The Grantor may at any time and at its sole discretion terminate this Agreement upon any breach by the Researcher of the terms and conditions of this Agreement.

9. CONFIDENTIALITY

9.1 During the negotiation and currency of this Agreement, the parties may disclose confidential information to each other in connection with work contemplated by this Agreement ("Confidential Information"). Each party will use reasonable efforts to prevent the disclosure of the other party’s Confidential Information to third parties for a period of three (3) years after the termination of this
Agreement, provided that the recipient party’s obligation shall not apply to information that:

(a) is already in the recipient party’s possession at the time of disclosure;
(b) is or later becomes part of the public domain through no fault of the recipient party;
(c) is received from a third party having no obligations of confidentiality to the disclosing party;
(d) is independently developed by the recipient party; or
(e) is required by law or regulation to be disclosed.

9.2 In the event that information is required to be disclosed pursuant to clause 9.1(e), the party required to make disclosure shall notify the other to allow that party to assert whatever exclusions or exemptions may be available to it under such law or regulation.

10. EVIDENCE

10.1 The entries made in the accounts maintained by the Grantor shall be prima facie evidence of the existence and amounts of the disbursements of the Grant made to the Researcher recorded in them.

11. ASSIGNMENT

11.1 This Agreement shall benefit and be binding on the parties, their permitted assignees and their respective successors. Any reference in this Agreement to either party shall be construed accordingly.

11.2 The Researcher may not assign or transfer all or part of its rights or obligations under this Agreement without the prior consent in writing of the Grantor.

11.3 The Grantor may assign all or part of its rights or transfer all or part of its obligations under this Agreement without the consent of the Researcher. Any such assignee or transferee shall be and be treated as a party for all purposes of this Agreement and shall be entitled to the full benefit of this Agreement to the same extent as if it were an original party in respect of the rights or obligations assigned or transferred to it.

12. REMEDIES, WAIVERS, AMENDMENTS AND CONSENTS

12.1 No failure on the part of the Grantor to exercise, and no delay on its part in exercising, any right or remedy under this Agreement will operate as a waiver thereof, nor will any single or partial exercise of any right or remedy preclude any other or further exercise thereof or the exercise of any other right or remedy. The rights and remedies provided in this Agreement are cumulative and not exclusive of any other rights or remedies (whether provided by law or otherwise).

12.2 Any provision of this Agreement may be amended or supplemented only if the Researcher and the Grantor so agree in writing and any provision or breach of any provision of this Agreement may be waived before or after it occurs only if the Grantor so agrees in writing. Any consent by the Grantor under any provision...
of this Agreement must also be in writing. Any such waiver or consent may be
given subject to any conditions thought fit by the Grantor and shall be effective
only in the instance and for the purpose for which it is given.

13. CONTRACTS (RIGHTS OF THIRD PARTIES)

13.1 A person who is not party to this Agreement has no rights under the Contracts
(Rights of Third Parties) Act Chapter 53B of Singapore to enforce any term of this
Agreement, but this does not affect any right or remedy of a third party which
exists or is available apart from the said Act.

14. COMMUNICATIONS AND NOTICES

14.1 Any notice required to be given by a party hereto to the other party shall be
deemed validly served by hand delivery or by telefax or by prepaid registered
letter or by a recognised courier service sent to its address or facsimile number
given herein or such other address or facsimile number as may from time to time
be notified for this purpose. The initial addresses and telefax numbers of the
parties are:

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<tr>
<th>The Researcher</th>
<th>NG Chong Ching</th>
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<td>Address</td>
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<th>The Grantor</th>
<th>Singapore Physiotherapy Association</th>
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</table>
| Address         | Physiotherapy Department, Singapore General Hospital
                 | Outram Road
                 | Singapore 169608
| Facsimile       | 63265495 |
| Attention       | Dr Celia Tan |

14.2 Any such notice or communication shall be deemed to have been served:

(a) If delivered by hand, at the time of delivery; or

(b) If posted by prepaid registered mail, at the expiration of three (3) days
    after the envelope containing the same shall have been put into the post;
or

(c) If sent by facsimile, upon the receipt by the sender of the transmission
    report indicating that the notice or communication has been sent in full to
    the recipient's facsimile machine, or such other similar medium of receipt;
or

(d) If sent by courier, at the expiration of two (2) days after the package
    containing the same shall have been received by the relevant courier
    company.

14.3 In proving such service it shall be sufficient to prove that delivery by hand was
made or that the envelope containing such notice or document was properly
addressed and posted as a prepaid ordinary mail letter or that the facsimile
confirmation note indicates that the transmission was successful, or, as the case
may be, the package containing such notice or document was properly addressed and sent to the relevant courier company.

15. **PARTIAL INVALIDITY**

15.1 The illegality, invalidity or unenforceability of any provision of this Agreement under the law of any jurisdiction shall not affect its legality, validity or enforceability under the law of any other jurisdiction nor the legality, validity or enforceability of any other provision.

16. **INDEMNITY**

16.1 The Researcher hereby irrevocably and unconditionally undertakes to indemnify the Grantor and keep the Grantor indemnified fully and completely against all claims, demands, actions, proceedings, losses, damages, costs (including legal costs on a full indemnity basis), expenses, liabilities and all other liabilities of whatsoever nature or description which may be made, taken, incurred, suffered or sustained by you in connection with or in any manner arising out of or as a result of the Research or this Agreement including, without limitation, any failure, refusal or neglect to observe and perform any of the covenants, undertakings, stipulations, terms and conditions contained in this Agreement.

17. **GOVERNING LAW AND JURISDICTION**

17.1 This Agreement shall be governed by, and construed in accordance with, the laws of Singapore. The parties hereto agree to submit to the non-exclusive jurisdiction of the courts of Singapore.

18. **ENTIRE AGREEMENT**

18.1 This Agreement contains the entire agreement between the Researcher and the Grantor on the subjects addressed herein and shall supersede any and all prior oral or written agreements or representations between the Grantor and Researcher, or agents and employees of either party.
IN WITNESS WHEREOF this Agreement has been entered into on the date stated at the beginning.

SIGNED by Ng Chong Ching

in the presence of: -

Witness
Name: Loy Pong Lian
NRIC/Passport No: [Redacted]

SIGNED by

on behalf of
Singapore Physiotherapy Association
In the presence of: -

CELIA TAN
President
Singapore Physiotherapy Association

Witness
Name: Maureen Loh Swee Suat
NRIC/Passport No: [Redacted]
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Months (Year 2007)
Appendix 6: Informed Consent Form

Informed Consent Form

Research Title: A single blinded study, on the difference in experimental induced mechanical pain threshold and tolerance between competitive contact and non-contact sports male athletes.

Principal Investigator: Ng Chong Ching, NIE post-graduate student, Physiotherapist

Purpose of research:
I have been informed that this study will test the difference in experimental induced mechanical pain threshold and tolerance between competitive contact and non-contact sports male athletes. This study will help physical therapists; coaches and trainers better understand the management of injured athletes.

Procedure:
I understand that I will be subjected to a experimental mechanical pain applicator. I will be tested for normal sensation prior to the experiment. I will truefully report the level of pain and stop the experiment when I felt the maximum amount of pain that I can tolerate. I am also allowed to stop the experiment at any point of time if I feel uncomfortable. I will be requested to be tested on 3 separate stimulated occasions.
I will be requested to:
1. not exercise prior one day to the testing.
2. not smoke or consume alcohol 24hours prior to the testing.
3. report to the investigator if I am on any medication.
4. report to the investigator if I am participating or had participated at any competitive sporting events that are 2 days before or after the testing dates.
5. declare if I have participated in such similar pain study as a subject.

**Risks and Discomforts:**

I understand that I will experience pain or discomfort during the experiment or post experiment for a short period of time. I understand that the pain stimulus is painful but non–harmful. I may have bruising on the test sites on the worst possible case. I understand that a qualified physiotherapist will be available to examine me for tissue injuries if necessary. An equipped first–aid box will also be available.

**Benefits:**

I understand that my participants in the study will have no direct benefit to me. I will be informed of my results (my personnel pain threshold/tolerance levels) as compared to the study groups only at the end of the entire experiment. The major potential benefit is for the better management of injured athletes by health care and sport injuries related professionals, coaches and sport trainers.

**Confidentiality:**

I understand that my identification and participation to this research will be kept confidential. Information of a sensitive personal nature will be stored in the investigator’s research file and identified only by a code number. The code key–connecting name to numbers will be kept in a separate secure location. If the data are used for publication in the medical/sports literature or for teaching purposes, no names will be used, and other identifiers, such as photographs and audio–
or videotapes, will be used only with my special written permission. I understand I may see the photographs and videotapes and hear the audiotapes before giving this permission.

**Request for more information:**

I understand that I may ask more questions about the study at any time. Chong Ching at HP: 98369105 or email: manualcircle@gmail.com is available to answer my questions or concerns. I understand that I will be informed of any significant new findings discovered during the course of this study, which might influence my continued participation.

**Refusal or withdrawal of participation:**

I understand that my participation is voluntary and that I may refuse to participate or may withdraw consent and discontinue participation in the study at any time without any prejudice. I understand that Chong Ching may terminate my participation in this study at any time after he has explained the reason(s) for doing so.

**Injury Statement:**

I understand that in the unlikely event of injury to me resulting directly from my participation in this study, if such injury were reported promptly, then medical treatment would be available to me, but no further compensation would be provided by the National Institute of Education, Singapore, or the investigator. I understand that by my agreement to participate in this study, I am not waiving any of my legal rights.
I have explained to ________________________________ the purpose of the research, the procedures required, and the possible risks and benefits to the best of my ability.

----------------------------------
Name/ Signature of Investigator Date

I confirm that Ng Chong Ching has explained to me the purpose of the research, the study procedures that I will undergo, and the possible risks and discomforts as well as benefits that I may experience. I have read and I understand this consent form. Therefore, I agree to give my consent to participate as a subject in this research project.

----------------------------------
Name/Signature of Participant Date

----------------------------------
Name/Signature of Witness Date
Appendix 7: Participant’s Information Form

Participant’s Information

Name:

Age:

Height (m): Weight (Kg):

Race: Chinese / Malay / Indian / Eurasian / Others: __________

Type of competing sport: __________________________

Duration of competitive sport experience (Years and Months):
___ years _____month(s)

Self-Perceived Measurement:
Place an “X” on the following lines to describe your self- perceived level of your sport.
I.e. Left represents low competitiveness and Right represents high competitive level.

- Competitive level:

  Low Competitiveness
  High Competitiveness

  Place an “X” on the following lines to describe your self- perceived contact level of your sport.
  I.e. Left represents low contact and Right represents high contact.

- Level of contact:

  Low Contact
  High Contact

  Place an “X” on the following lines to describe your self- perceived pain tolerance level.
  I.e. Left represents low tolerance and Right represents high tolerance level.

- Level of pain tolerance:

  Low Pain Tolerance
  High Pain tolerance
(Supported by Singapore Physiotherapy Association Research Grant no: RF00600. Ng Chong Ching can be reached at: Chong Ching <manualcircle@gmail.com>)