

**An investigation into pain threshold and tolerance differences between Brazilian Jiu Jitsu athletes and a commensurate group of high-intensity training, aerobic and resistance athletes.**

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A research thesis submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy, Unitec Institute of Technology, New Zealand



## Declaration

Name of candidate: **Vance Miller**

This thesis titled '**An investigation into pain threshold and tolerance differences between Brazilian Jiu Jitsu athletes and a commensurate group of high-intensity training, aerobic and resistance athletes**' is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

### **Candidate's declaration**

I confirm that:

- This thesis represents my own work
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee
- Ethics Approved by the Unitec Research Ethics Committee. UREC approval number: 2014-1112

Candidate Signature: ..... Date: .....

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## **Acknowledgements**

Thank you to Jamie Mannion, my principal research advisor for your assistance and support throughout this research. I am also grateful to AUT and David Rice for allowing me to use their research facilities for the purpose of data collection.

I am grateful to all of the individuals who gave their time to participate in this research project. I appreciate your willingness to endure and experience experimental pain on multiple occasions. I appreciate the people in charge of the exercise facilities who allowed me to discuss my research with their members during the recruitment phase of this research.

Thank you to all of my teachers and tutors throughout the undergraduate and postgraduate programme for your guidance and support. A big thanks to my classmates who shared the experiences with me along the way.

Finally, a big thank you to my family and friends who have supported me throughout this journey, enduring and embracing the rollercoaster ride as if it was their own. I am very grateful for all the help I have received along the way.

## **Preface**

This 90-credit quantitative thesis is submitted in partial fulfilment of the requirement for the Master of Osteopathy degree at Unitec Institute of Technology.

The following thesis is divided into three sections;

1. Literature Review: This literature review commences with a background on pain. Some of the negative connotations are discussed along with physiological adaptations to pain. Treatment approaches to pain are then incorporated, leading into reviews of different exercise modalities involving pain, including martial arts, identifying gaps in literature where future research is required. This literature review provides a basis for the manuscript.
2. This manuscript, titled ‘An investigation into pain threshold and tolerances differences between Brazilian Jiu Jitsu athletes and a commensurate group of high-intensity training, aerobic and resistance athletes’ compares the effects of two high intensity exercise modalities on pain threshold and tolerance adaptations. This manuscripts is styled for the *Journal of Sports Behavior*.
3. Appendices: The appendices include ethics documentation, participant information and consent forms.

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## **List of abbreviations**

Brazilian Jiu Jitsu	BJJ
Central Nervous System	CNS
Central sensitization	CS
Cognitive Behavioral therapy	CBT
Control conditioning	CON
High intensity training	H.I-Training
Kilopascals	kPa
Kilopascals per second	kPa/s
Martial Arts	MA
Pressure pain threshold	PPT
Standard Deviation	SD

## **Section I: Literature Review**



## **1. Introduction**

In most contact sports, such as boxing or Brazilian Jiu Jitsu (BJJ), the ability to tolerate and (block out) pain appears to be essential in allowing the participant to perform at a high level (Dean Ryan & Kovacic, 1966). Comparatively, in non-contact sports, the need to withstand pain appears to be less essential due to the low probability of pain exposure during performance. Therefore, it may be conceivable that an athletes' ability or inability to tolerate pain could be related to the type of sport (contact or non-contact) that they partake in on a regular basis. Athletes who possess high pain thresholds (minimum point at which the pain is sensed as pain) and tolerances (the maximum amount of pain one may voluntarily endure) may therefore excel faster than individuals with low pain thresholds/tolerances.

BJJ can be likened to a form of kinetic chess. This high intensity martial art is of Japanese origin and is a weapon free system of maneuvers, pressure and manipulation used to subdue an opponent. Its creation derived from the fact that, on the battle field a Samurai could lose his weapon at any time and would need a weaponless method of defense. Due to body armor, traumatic strikes were not effective, and it was maneuver's and manipulations that became the most effective method of defense and attack. In the early 1900's this traditional Japanese Jiu Jitsu made its way to Brazil, at which point the Gracie family developed and perfected the art to form Brazilian Jiu Jitsu. BJJ is now widely used in competition, incorporating high intensity aerobic and resistance exercise in multiple rounds lasting 3 to 10 minutes and is also a major component in modern mixed martial arts (Gracie, Gracie, Azoury, & Peligro, 2001).

In BJJ, it is desirable and advantageous to possess a high pain threshold and tolerance. (Gracie, Gracie, Azoury, & Peligro, 2001). A key objective of BJJ as a martial art is to force the opponent to 'tap out' (physically tap the ground or opponent to signal submission, thereby ending combat) using various attacks and submission holds. A submission hold is the equivalent of checkmate in the sport, reflecting a disadvantage which would be extremely difficult to overcome in a fight. Such attacks/submission holds include 'chokes' (either occlusion of carotid blood supply or compression of the trachea), joint locks (e.g., forced hyperextension or rotation), 'crushers' or 'cutters' (focused pressure typically on a myotendinous junction), suffocation or the causation of general overall discomfort. Subsequently, BJJ athletes are constantly being exposed to their pain tolerance, which means in order to improve performance in BJJ a participant must learn to tolerate increased pain and discomfort (Gracie et al., 2001). It is commonly observed that beginners do

not tolerate submission attempts as well as advanced athletes. The cause for this is unclear, as it is not known if these observations are owing to alterations in the cognitive appraisal of pain, or to changes in the transmission or processing of nociceptive signals.

A thorough understanding of pain is useful to exercise scientists, as well as clinical sports medicine specialists, as pain is an integral part of exercise and sport (O'Connor, Chapman, Myers, & Cook, 1999). Although it is not clearly understood, Focht, Bouchard, & Murphey (2000) and Koltyn & Arbogast (1998) suggest acute bouts of high intensity aerobic and resistance exercise are associated with acute analgesic responses to clinically induced pressure pain. This claim partially dictates the direction of this project, which is designed to assess the difference in pain thresholds and tolerances to experimental pain between BJJ athletes and a commensurate group of athletes who train to a similar intensity, without the same exposure to pain.

This research will provide data which will aid in determining whether it is plausible to conduct a longitudinal study on pain habituation in athletic populations. The purpose for a longitudinal study would be to further assess if regular exposure to nociceptive stimuli is more beneficial than high intensity aerobic and resistance training alone, in altering an individuals' analgesic response to clinically induced noxious stimuli. The results from this study will help researchers and clinicians of pain to better understand nociception and pain in relation to sports and exercise. This literature review will overview several fundamental issues about the nature of pain and the measurement of pain so that clinicians and researchers can more effectively read, evaluate, and conduct research on topics relating exercise and pain. This knowledge may provide a foundation to stimulate further research in the direction of pain conditioning, with a potential application in pain management. Advancing knowledge in this field would be of benefit as information about nociception and pain has not received systematic coverage in either exercise science text books or the sports medicine literature (Wells, Kolt, Marshall, & Hill, 2013).

## **2. Pain**

### *2.1. Definition*

Pain was defined in the 1980s by a committee organized by the International Association for the Study of Pain (International Association for the Study of Pain, 2014). This definition was then revised and updated in the 90s to incorporate later discoveries within pain science and has since been widely accepted within the pain science community (Simon van Rysewyk, 2010). Pain is the definition of “An unpleasant sensory or emotional experience associated with actual or potential tissue damage or described in terms of such damage” (International Association for the Study of Pain, 2014).

Although pain can be useful in signaling injury and initiating a variety of responses in order to cease and mend its causes, it can also be a constant and life altering issue which is commonly presented to primary and secondary health care practitioners alike within the public health system (Glajchen, 2001). Godfrey (2005) and Pfizer (2013) point out that pain can affect physical, psychological and social aspect of health, inhibiting and altering activities of daily living and decreasing quality of life.

### *2.2. Economic impact of pain*

Chronic pain, defined as daily pain for a minimum period of 3 months (Bouhassira, Lantéri-Minet, Attal, Laurent, & Touboul, 2008) remains a large burden on the economy and the public health care system. The work force is affected via loss of productivity and absentees due to chronic pain, and the public health care system is heavily impacted through high numbers of compensation claims and healthcare costs, including doctor visits, diagnostic investigations, medications, manual therapies and other forms of treatment (Pfizer, 2013).

A 2007 report by Access Economics into the economic cost of chronic pain in Australia, estimated that the indirect cost to the community per person with chronic pain is \$10,847 per annum (Pfizer, 2013). Access Economics also carried out a study in New Zealand, assessing the economic cost of a common chronic pain condition, being arthritis. The report, published in 2010, found that the total economic cost of arthritis for the year 2010 was an estimated \$3.20 Billion, comprised of health-sector costs and indirect costs (McCook, Ayling, & Cappo, 2010).

### *2.3. Subjective nature of pain*

The understanding of pain remains complex partly due to its subjective nature. Each person understands the meaning of pain through early life experiences usually associated with injury and illness. People learn to recognize that stimuli that produce pain are also likely to cause tissue damage. Consequently, we understand pain as relating to actual or potential tissue damage. Pain is certainly always felt in an area or areas of the body, but it is also a psychological experience. This is due to pain always being an unpleasant experience and therefore an emotional experience. There are some experiences which could be misunderstood as pain (such as pricking), however, if the experience is not unpleasant then it cannot be labelled 'pain'. Controversially, unpleasant sensations such as dysesthesias may be perceived as painful, but not definitively so, due to the lack of sensory qualities of pain (Melzack, 2001). Having a clear understanding of pain can also affect a persons' ability to tolerate pain. In a setting such as martial arts training, the athlete has the understanding that pain is inevitable and will likely cause no harm. This can help the athlete to push through the pain and be content with experiencing the unpleasant qualities of pain.

### *2.4. Comparing Acute and Chronic pain*

Pain, being an essential aspect of the nervous system, provides the body with a warning or potential or actual tissue damage. There are emotional factors effecting pain, however, it is largely sensory and starts at the site of pain receptors. These are referred to as nociceptors (specialized sensory receptors responsible for the detection of noxious (unpleasant) stimuli. This stimuli is then transferred to electrical signals, which are then conducted to the central nervous system (Braz, Nassar, Wood, Neuron, & 2005). The signal makes it way the thalamus, which in turn gates and relays pain signals to the cerebral cortex to be acknowledged as 'pain' (Seymour, 2012). The nociceptors are the free nerve endings of primary afferent nerve fibers which are located throughout the body (skin, muscle, viscera, joints, meninges) and can be stimulated via mechanical, thermal and chemical stimuli (Almeida, Roizenblatt, research, & 2004). In a clinical situation, these pain sensations would be stimulated with pressure algometry, cold pressor tests, and saline injections.

Pain can be classified into two main categories (acute and chronic). Acute pain is usually of short duration, lasting no longer than six months. This category of pain is sometimes associated with physiological tissue damage and promotes awareness through activation of nociceptors, leading to a response such as withdrawing a limb from danger. This aspect of pain is an influential factor in sport, particularly martial arts, being that it is more beneficial to avoid extreme acute pain in order to prevent submitting to your opponent. Whether engaging in martial arts or not, often, the cause of acute pain is known, and treatment is readily available if required, often resulting in healing and the resolution of pain. Acute pain can often illicit an initial emotional response, some of which include fear avoidance behaviors and anxiety, aiding in keeping an individual from engaging in activities which may lead to further harm. In turn, this provides rest and promotes immobilization to an extent to allow for healing to take place. Examples of acute pain include ligament sprains, bone fractures, child birth, and burns (Campbell, 2011).

Pain, on the other hand, serves no purpose in preventing or warning us of potential injury or disease, leaving it plausible to suggest the pain in and of itself is the disease (Melzack, 2001). The experience of chronic pain was once considered straight forward and potentially occurred due to pain processing errors. When considering pain processing through noxious input and its signal delivery to the cerebral cortex, chronic pain should result from too much afferent input, or hypersensitivity to normal stimuli. However, therein remains the problem, as chronic pain often occurs in the absence of any nociceptive input, unlike acute pain (Seymour, 2012). This highlights the complexity of chronic pain and how much we do not yet understand about its properties.

Chronic pain interferes with everyday life, affecting physical, emotional, and spiritual health, as well as financial stability, relationships, and self-confidence to name a few (Field & Swarm, 2008). As pain develops into a chronic state, psychological factors in particular play an increasing role in pain coping strategies and pain perception. Dysphoric mood states such as helplessness, anxiety, depression, and apathy are experienced by people with chronic pain. Also, behavioral responses including limited activities, sleep deprivation, and social withdrawal (Field & Swarm, 2008). The following diagram (See Figure 1) represents a cycle that many chronic pain sufferers experience.

When considering the therapy of acute pain, often the aim is to target the underlying cause and interrupting the nociceptive signals. Chronic pain therapy however, must rely on a multidisciplinary approach, involving several therapeutic modalities (Grichnik & Ferrante, 1991). Several of these treatment modalities will be explored in further detail under the ‘pain management’ section, with an attempt to uncover some of their pain adaptive qualities shared with martial arts and exercise.

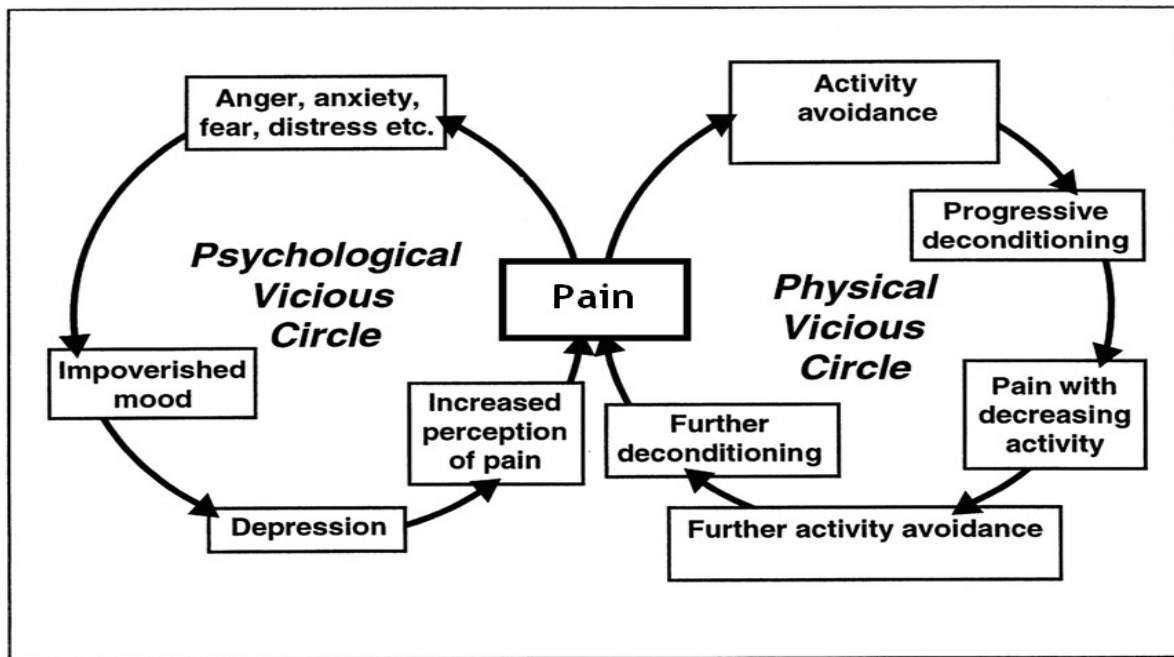


Figure 1. Pain cycle. Describing the psychological and physical cycle of pain

Source: Cooper, R. G., Booker, C. K., & Spanswick, C. C. (2003). What is pain management, and what is its relevance to the rheumatologist? *Rheumatology*, 42(10), 1133–1137. <http://doi.org/10.1093/rheumatology/keg313>

### 2.5. Fear-avoidance beliefs

Psychological factors, such as (but not limited to) increased perception of pain, play a fundamental role in the development of chronic pain. Furthermore, increased perception of pain is often a precursor to pain related anxiety, anger, distress and leads to fear avoidance from activities (physical, professional, and social) which patients associate with the exacerbation of pain, even once the initial injury has healed (Vlaeyen & Linton, 2000).

During the acute phase of pain, the adaptive pain-related fear avoidance response promotes rest and recovery, however, this avoidance behavior can continue after the injury has healed. In this case, patients who exhibit pain-related fear avoidance behaviors are likely to develop poor behavioral performance, hypervigilance to internal and external illness/injury information, muscular reactivity, and physical disuse in terms of deconditioning and guarded movement (Campbell, 2011).

Fear-avoidance beliefs are not always permanent, having the ability to be suppressed by engaging in specific therapies and/or activities, such as martial arts. BJJ is a martial art which is thought to have an impact on fear avoidance beliefs and pain perception. It is commonly observed that beginners in BJJ have a heightened perception of pain, and consequently submit early and often due to their fear of pain (Gracie et al., 2001). However, constant exposure and practice leads to the understanding that pain, in this context, is not necessarily harmful, but rather, a necessary aspect of the art and can be overcome with positive thinking, experience and will power.

#### *2.6. Sensitization and Pain*

The presence of pain itself can alter how an individual perceives pain, in such a way that the patient becomes more sensitive and experiences more pain with less provocation. This pain related sensitization is called 'central sensitization' (CS) due to changes that occur in the central nervous system (CNS) (Ingraham, 2011). It is thought that this neurological complication is a major common denominator in the majority of difficult pain problems, potentially being the *cause* of the chronicity, regardless of how the pain started (Ingraham, 2011).

It is plausible that there may be biological, psychological and environmental predisposing factors for the development of CS and Chronic pain. It has not yet been addressed through research, but pain thresholds, which are likely due to multiple genetic factors (Phillips & Clauw, 2011), could play a causal role in the development of CS and lower pain thresholds. Psychophysiological factors, one being the stress-response, also provide a pathway for the development of CS.

### 3. Stress

Stress is an indication of allostasis taking place. Allostasis is the process of achieving stability or homeostasis, through physiological and behavioral change (Szanton, 2005). Usually in response to a threatening stressor in the internal or external environment, including contact sports. A stressor is any stimuli which consequently results in a stress response at both psychological and physiological levels. Stress can be induced in response to a wound (Blackburn-Munro & Blackburn-Munro, 2003; Melzack, 2001), witnessing or perceiving pain in another individual (S van Rysewyk, 2009; Simon van Rysewyk, 2010), as well as internal dysfunction. The bodies reactions produced in response to a stressor depends on multiple factors; if the stressor is positive or negative, duration, frequency, and intensity of the stressor applied. Prospective and experimental studies on humans (Kuehl, Michaux, Richter, & Schächinger, 2010; Rivat, Becker, Blugeot, Zeau, & Mauborgne, 2010; Slade, Diatchenko, & Bhalang, 2007), have shown a decrease in pain thresholds in response to stress. Correlating with stress, pre-existing anxiety towards pain is also related to decreased pain thresholds (Hirsh, George, Bialosky, & Robinson, 2008)

The stress response also varies based on the context in which the stressor is applied. When considering martial arts; cognitive processes, such as expectations, past experiences, acknowledgment, and beliefs can all alter the context in which the physiological response occurs (Ehde, Dillworth, & Turner, 2014). Initially, it is usually noxious stimuli detected by sensory afferent nerve fibers which lead to the stress response, which is then influenced by negative or positive thinking. For example, when a novice martial artist who has been training for one week experiences pain, he is likely to have higher expectations and attributes towards the pain they're about to experience. An experienced martial artist, however, will likely have better pain coping strategies and cognition responses when dealing with pain, which may lead to pain inhibition (K Koltyn, 2003; KF Koltyn & Arbogast, 1998; Sullivan, Bishop, & Pivik, 1995).



#### **4. Anticipation and suppression**

It has long been hypothesized that anticipation of pain, in certain instances, may influence the experience of noxious and non-noxious stimulation (Sawamoto, Honda, & Okada, 2000; Staub, Tursky, & Schwartz, 1971). The anticipation of pain may involve the influence of multiple qualia. The influences include anxiety, systemic physiological arousal (heart rate and breathing rate), cognitive appraisal, and distributed attention from the source and body location of noxious input (Sawamoto et al. 2000). The level at which these qualia effect the subject may vary based on previous experiences (Hsieh, Stone-Elander, & Ingvar, 1999). Typically, anticipation of pain helps individuals to avoid experiencing potentially harmful situations, however, for the people experiencing chronic pain, it can become dysfunctional, leading to anxiety and fear avoidance behaviors (Chapman, 2010; Kruger, Light, & Chapman, 2010).

Suppression of pain is another mechanism of coping with painful situations. Athletes injured in sports (including martial arts), as well as soldiers wounded on the battle field have often reported not feeling pain at the time of injury (Amit & Galina, 1986; Richard & Gloster, 2007). It has been noted by Rhudy and Meagher (2000) that anticipation and/or fear of an external painful stimulus can lead to activation of endogenous opioids, leading to suppression of pain, whereas individuals who have anxiety will often report experiencing greater levels of pain. The release of endogenous opioids effects nociception and homeostatic functions following wounding (Rittner & Stein, 2005). In a martial art setting, it is plausible that the athlete often anticipates and accepts pain as inevitable, which can decrease anxiety levels and may lead to the endogenous opioid release explained by Rhudy and Meagher (2000).

#### **5. Homeostasis and Allostasis**

Homeostasis governs maintenance within the body (McEwen & Wingfield, 2003, 2010; McEwen, 2004). When homeostasis is compromised, adaptation must occur to ensure the processes and functions maintaining homeostasis stay within their threshold limit. This interdependent physiological and adaptive reaction is known as allostasis (S van Rysewyk, 2013). Simply put, homeostasis maintains life, whereas allostasis enables individuals to adapt to life. When considering exposure to repetitive pain, as experienced in martial arts, the allostatic adaptations occurring largely involve pain habituation.

The phenomenon of pain habituation occurs when repeated noxious stimuli elicit progressively smaller responses (Glaser & Griffin, 1962; Milne, Kay, & Irwin, 1991). This phenomenon appears to be broad, spanning across all sensory modalities. This phenomenon is commonly observed in martial arts and exercise (Ellingson, Koltyn, Kim, & Cook, 2014), however, the neurobiological mechanisms which are responsible for this phenomenon are still to be defined (Ellingson et al., 2014). Some of the mechanisms by which allostasis works to serve homeostasis and potentially lead to habituation is via the production and release of certain hormones, such as cortisol, epinephrine, norepinephrine, corticotropin-releasing hormone, and multiple mediators such as calcitonin gene-related peptide, substance P, and cytokines. These hormones aid an individual in adapting to pain and injury. This recruitment of endogenous hormones and mediators is the core stress response to the challenges of a stressor, offering further insight into some of the adaptation mechanisms which may be activated in martial artists.

## **6. Management of Pain**

### *6.1 Medication*

Pain is a very common complaint within the public health system, presenting to primary and alternative healthcare practitioners alike (Glajchen, 2001; Gourlay, Heit, & Almahrezi, 2005). For millennia, opioids have been used to treat pain, and remain in high demand today, being one of the most commonly prescribed medications for acute and chronic pain (Trescot, Helm, Hansen, & Benyamin, 2008).

### *6.2 Cognitive behavioral therapy*

The experiences and adaptive changes occurring through martial arts participation can be likened to those involved in Cognitive-behavioral therapy (CBT). As the unexperienced novice engages in martial arts, they often appear to fear pain and consequently submit early. After more time being exposed to pain in this environment they learn that pain, in this context, will unlikely cause harm and does not need to be feared. This has similarities CBT, a more traditional method of changing fear evaluation. CBT therapy is a treatment aimed at improving patients' quality of life and limiting psychological distress through the retraining of maladaptive thoughts, feelings, and behaviors, in addition to teaching adaptive ways of coping with targeted problematic behaviors (Ebert & Kerns, 2010).

CBT is shown to be effective through positively treating a range of disorders, from depression and anxiety, to chronic pain (Ebert & Kerns, 2010). The use of CBT on patients with chronic pain stems from the notion that pain is a complex experience associated with both underlying pathology, emotions, thoughts, and behaviors (Ebert & Kerns, 2010). CBT, when used for the treatment of chronic pain, targets patients dysfunctional cognitive and behavioral coping strategies and pushes people to take on perceptions of heightened personal control relating to pain. This is relatable to the pain coping strategies undertaken when martial artists first begin their training journey. Initially martial artists may find it difficult being exposed to pain, and their way of coping is often to submit early to terminate the experience. However, through constant training, guidance and repetition, the martial artist can learn to accept pain as unavoidable and discover that pushing through the pain can lead to desirable outcomes, such as not losing a match or submitting their opponent in return. Succeeding in martial arts requires cognitive and behavioral adaptations to pain, not too dissimilar from CBT, which implements flexible and active problemsolving approaches to pain management (Ehde, Dillworth, & Turner, 2014).

Even though there is research supporting the efficacy of CBT in the treatment of chronic pain, the benefits, on average, are mediocre (Morley, Eccleston, & Williams, 1999). CBT does possess its limitations, with a noticeable gap being the lack of randomized controlled trials of CBT tailored to adults by low literacy, racial/ethnic minority status, and rural residence (Campbell, 2011). CBT treatment protocols assessed in randomized controlled trials also vary largely in their content, format, and dose. It remains unclear as to what CBT methodologies, components, and dosages are optimum for chronic pain sufferers. There also remains a need for standardization of measures across trials for delivery of results in terms of clinical and statistical significance, as well as combining results for meta-analysis (Dworkin, Turk, Farrar, & Haythornthwaite, 2005; Dworkin, Turk, Wyrwich, & Beaton, 2008). With limited knowledge surrounding CBT and chronic pain, alternative avenues for chronic pain management remain of interest and are worth exploring. Due to the complexity of this type of pain, any research, both direct and indirect will be valuable in helping researchers better understand chronic pain management. Due to the potential for similar pain adaptation outcomes through CBT and martial arts engagement, it may be beneficial to study these two modalities together. One modality could offer insight to enhance the other through exploring variations in coping strategies.

### 6.3. Graded in vivo exposure

Psychological treatments have gained popularity in recent decades, particularly therapies based on cognitive behavioral principles. Another treatment which appears to hold similar qualities to martial arts participation is Graded in vivo exposure. It is common practice in martial arts for the athlete to gain experience and overcome fear-avoidance behaviors through graded pain and training exposure. When first engaging in martial arts, it is not uncommon for a new participant in martial arts to be fearful of contact and conditioning, and for this reason, training typically starts at a beginner level with light contact and sparring. To a beginner, this can still be very unpleasant and painful. However, as the athletes confidence and skill level rises, their fear avoidance behaviors tend to decrease, allowing them to engage in a higher level of contact with greater exposure to pain (Gracie et al., 2001). As a martial artist advances through the ranks, they can typically tolerate what would have been intolerable at the beginning of their training journey.

This form of gradual exposure to an uncomfortable activity, shares qualities of graded in vivo exposure. A graded in vivo exposure treatment has been developed based on the fear-avoidance model of chronic pain, to expose patients to certain movements which they associate with the exacerbation of their pain levels. This graded in vivo exposure has shown benefits in multiple case studies. (Macedo, Smeets, Maher, Latimer, & Mcauley, 2010) systematically reviewed 15 randomized controlled trials with a total of 1,654 patients on the effectiveness of graded activity and graded in-vivo exposure for the management of lower back pain. The available evidence suggests that graded activity in both the short and medium term is more effective than minimal intervention but not more than other forms of exercise for persistent lower back pain. Other notable improvements observed in multiple studies for graded in vivo exposure included improved measures for fear of pain/movement, pain related anxiety, and fear avoidance beliefs (Macedo et al., 2010; Woods & Asmundson, 2008).

Despite the benefits graded in vivo exposure therapy can provide, there are many practitioners in the field of psychotherapy who have public relations issues with this form of treatment (Richard & Gloster, 2007). The negative views surrounding this treatment appear to stem from the stress evoking nature of this therapy (although temporary). Feeney, Hembree, and Zoellner (2004) have discussed the negative connotations of graded in vivo exposure and have the opinion that the outcome does not warrant the treatment, due in part to its lack of sensitivity to the patients' needs; its lack of efficacy on complex cases; its exacerbation of symptoms and cause for high rates of

attrition; and its insensitive techniques that are done “to” the patient, rather than “with” them.

## **7. Exercise and Pain**

For decades, exercise and pain has been of interest to researchers (Koltyn, Wertz, Gardiner, & Nelson, 1996). The use of exercise in the treatment of pain started to take root in the early 90's (Anshel & Russel, 1994), which has since lead to the majority of pain management programs incorporating some form of exercise as part of the treatment strategy (Koltyn & Arbogast, 1997). Koltyn and Arbogast (1997) have demonstrated pain attenuation responses to intense exercise, and it has also been revealed that noradrenergic and opiate systems activate in response and in proportion to the intensity and length of exercise (Vierck, Staud, Price, & Cannon, 2001). The lack of painful stimuli noted to activate the transient analgesic effects in Vierch et al (2001), indicate that there may be another mechanism, applicable to conditioned BJJ athletes, for which the analgesic effects producing pain tolerance adaptations occurred.

Regarding chronic adaptations to exercise, there exists extensive evidence showing that athletes exhibit an increased pain tolerance (maximum amount of pain voluntarily endured) compared with normally active adults (Henchoz & So, 2008; Koltyn, Wertz, Gardiner, & Nelson, 1996; Koltyn & Arbogast, 1997). Kolt (2000) suggest two potential explanations for higher athlete pain tolerance adaptations when compared with non-athletes;

1. Athletes have a greater exposure to physical training and increased fitness, resulting in higher levels of circulating endogenous opioids.
2. Athletes, as part of their physical training and performance explore boundaries in relation to extreme physical activity and pain experience, giving them a perception of control over the pain-physical activity interface. It has been suggested that ‘knowledge is the great liberator!’, and education and understanding is the primary step towards the management of pain (Moseley & Butler, 2003). It has also been hypothesized that the development of coping strategies needed to overcome unpleasant sensory experiences when training play a role in pain tolerance adaptations (Fernandez & Turk, 1989). In this regard, changes in pain threshold (defined as the smallest stimulus required to be perceived as painful), are less commonly found in sports and athletic disciplines. It is argued that the pain threshold represents a physiological marker of pain stimuli that is not influenced by cognitive appraisal (Fernandez & Turk, 1989).

Not dissimilar from the observations noted by Koltyn and Arbogast (1997), it is likely that changes in coping strategies and cognitive appraisal also occur with BJJ athletes. However, the different stimuli faced in BJJ (higher intensity of pain via submission holds, often due to pain tolerance limitations being reached) may evoke changes not typically observed in other athletes (Andreato, Franchini, & Moraes, 2013). Indeed, studies that have investigated repeated painful stimulation using a daily painful-stimuli for one week have reported changes in thermal pain thresholds (Rennefeld et al., 2010). These changes are termed ‘habituation’ and represent peripheral as well as central adaptations to repeated painful stimuli. While the exercise induced analgesia and experimental pain habituation are widely reported phenomena, research regarding the impact of martial arts on pain perception remains equivocal.

## **8. Martial arts and Pain**

Due to systematic exposure to brief periods of intense pain during training or competition, athletes need to learn how to effectively deal with these experiences. Having control over the sensation of pain is an essential aspect of sport participation and is especially desirable in combat sports. Martial artists, in particular, require the ability to tolerate pain as there is direct exposure to bouts of intense pain in training or competition with opponents (Leznicka, et al., 2016). An investigation into the relationship between martial arts and pain adaptations has revealed only a small number studies addressing potential causative links. Evidence suggesting martial arts has an impact on pain tolerance and thresholds remains largely empirical. A literature search in PubMed, Google Scholar, and Science Direct data bases was undertaken with the following key words: Martial arts, Pain, Pain Tolerance, Pain Threshold, Pain Habituation. This revealed 346 pages of results between the data bases. Titles were screened for martial arts and pain interventions, with twenty-eight articles being selected based on relevance to this study. Following this process of article selection, abstracts were screened in greater depth for a martial arts intervention program for a selected time period of at least two weeks, with an outlined measurement-criteria involving either pain thresholds or tolerances. Twenty-eight abstracts were screened between the chosen data bases (and google scholar), with only three meeting the criterion for inclusion.

Fotch, Bouchard, and Murphey (2000) investigated the effect of martial arts training on experimentally induced pressure pain, anger, and physical self-efficacy. Participants (n=30) of both genders were divided into two groups (control conditioning CON; n=15 and martial arts conditioning MA; n = 15) and undertook a 14-week pre and post training investigation. The form of martial arts which was utilized was not reported, limiting the reliability of the study. Knowing which type of martial art was used would assist in knowing what level of contact, if any, was incorporated into the martial art. Results indicated that there was a significant increase in pain threshold as well as a significant decrease in pain ratings for a standardized stimulus when compared to baseline measures following the MA conditioning. It remains unclear as to why there is a lack of information regarding which martial art was utilized for the study. Consequently, there remains a gap in knowledge regarding which martial arts modality can provide such pain adaptations, and whether the results were affected by contact in the martial arts intervention group. This information would offer insight into whether the pain adaptations involved physiological as well as psychological adaptations.

Leznicka et al., (2016) produced a study which revealed similar results. The study compared 140 male martial artists, aged between 18 – 28, with a control group of men aged between 18-26, who were not involved in any sports at a professional level. The two groups were assessed for pain tolerance and thresholds through cold pressor testing and pressure pain testing. The tools utilized for testing thermal and mechanical pain (cold pressor apparatus and a pressure algometer) were reported to be adequate and reliable methods of assessing pain tolerance levels. Results favored the martial arts group, with measures revealing significantly higher tolerances to harmful cold and mechanical stimulation, as well as a significantly higher mechanical pain threshold ( $p < 0.001$ ).

Dirkwinkel, Gralow, and Colak-Ekici (2008) were interested in the effects of repeated painful stimuli (as an inurement exercise) which are often performed in some Asian martial arts to alter pain perceptions. Kung Fu disciples (n=15) struck their forearms and lower legs with a foam covered stick daily for 2 minutes over 14 days. A comparison group of healthy active adults who were performing sports without contact during this period was included. Measures of trigeminal pain intensity from electrical stimulation showed a significant decrease in the experimental group, whereas the control group did not show any changes of sensory or pain perception during the study period, indicating changes in central sensitization and inhibitory control mechanisms in the nociceptive spinal or cerebral pathways. Another small change in pain threshold was also noted in the experimental group whereas the control group appeared to have a significant decrease in pain thresholds. Results may be biased however, due to the selected populations against which the comparisons were made. Conducting further conditioning on already conditioned Kung Fu disciples and comparing against 'healthy active adults' would likely shift results in favor of the martial artists.

## **9. Experimental Pain**

Historically, pain has been of great interest to the scientific, healthcare, and sporting communities. Over time, this has led to the development of various experimental pain testing methods to assist in researching sensory and perceptual mechanisms of pain (Glajchen, 2001). Common methods of experimental pain testing include cold pressor tests, pressure pain tests, saline injection tests, and electrical pain tests (Lötsch et al., 2016). Screening experimental pain research has revealed cold pressor testing and pressure pain testing as two of the more commonly used methods for clinical research. Saline injections and electrical stimulation had greater incidences of invoking psychological fear-avoidance responses which limited test reliability (Lötsch et al., 2016). Cold pressor testing is widely used in both adult and pediatric populations, as it is both ethically acceptable and can be used with relative ease (Mitchell, MacDonald, & Brodie, 2004; Mitchell, 2004). This method of experimental pain induction requires the participant to submerge their hand into circulating water which is maintained at a specific temperature. Verbal or visual pain scales are generally used as time is recorded to assess pain threshold and tolerance levels. Although the cold pressor test is widely accepted and used for clinical research, studies have identified methodological inconsistencies with testing procedures which can limit test reliability (Mitchell, MacDonald, & Brodie, 2004; Mitchell, 2004). To limit inconsistency, it is recommended to maintain clear communication on what is expected



(threshold/tolerance) with replicated instructions for each participant, constant room temperature, and maintain consistent water temperature.

Similarly, pressure pain testing is also widely used in adult pain testing and ethically acceptable, with pressure algometers being the primary tool for application (Chesterton, Sim, Wright, & Foster, 2002; Vaughan, McLaughlin, & Gosling, 2007). The pressure algometry method of pain testing has been evaluated for intrarater, interrater, and test-retest reliability, with positive results supporting its use as an adequate and reliable research tool (Walton et al., 2011). Intrarater reliability was reported as almost perfect, interrater reliability was substantial to near perfect, and test-retest reliability was substantial. Limitations with application were noted as inconsistent pressure application, either too fast/slow or varying speeds, poor instructions, and inconsistency with application site anatomically. Even though there is the potential for rater error, Walton et al., (2011) provide evidence that novice raters can perform pressure algometry with adequate reliability for clinical research.

## **10. Conclusion**

Pain is of clear clinical importance and the identification of effective methods to reduce or manage pain is imperative to health, recovery and wellbeing. Currently, there exists multiple treatment options ranging from graded in vivo exposure to cognitive behavioral therapy, and medication for different pain states. These do however, all possess their faults and there is room for a new protocol aimed at individuals with a heightened perception of pain. As pain develops into a chronic state, psychological factors, particularly have an increasing role in pain coping strategies and pain perception. Dysphoric mood states such as helplessness, anxiety, depression, and apathy are very real for many chronic pain sufferers. Also, behavioral responses including limited activities, sleep deprivation, and social withdrawal (Field & Swarm, 2008). For this reason, there may be potential for an exercise-based regime included in a treatment protocol targeted at both physiological and psychological aspect of pain, as exercise induces endorphin release, which in turn leads to decreased feelings of pain, feelings of euphoria, sex hormone release, and decreased stress levels (Dishman & O'Connor, 2009). It is also plausible that some of the pain adaptations and habituation phenomena observed in sporting and experimental studies is also manifested in the martial art of BJJ. If this is indeed the case, certain aspects of BJJ may be explored in future as a potentially beneficial activity for individuals who are in pre-central sensitized states, due to the adaptations which may result from participation.

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## **Section II: Manuscript**

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**List of abbreviations**

Brazilian Jiu Jitsu	BJJ
Central Nervous System	CNS
Central sensitization	CS
Cognitive Behavioural therapy	CBT
Control conditioning	CON
Kilopascals	kPa
Kilopascals per second	kPa/s
Martial Arts	MA
Pressure pain threshold	PPT
Standard Deviation	SD
High Intensity training	H.I. Training

## **Abstract**

**An investigation into pain threshold and tolerance differences between Brazilian Jiu Jitsu athletes and a commensurate group of high-intensity training, aerobic and resistance athletes.**

**Background:** High-intensity aerobic and resistance exercise is known to raise pain tolerance. There is also some data indicating that participation in high contact martial arts may increase pain tolerance and threshold, however, studies have not been well controlled for the effect of exercise.

**Aim:** The aim of this study was to compare pain tolerance and thresholds between both contact and non-contact athletes who train to a similar intensity.

**Methods:** Thirty-nine pain-free volunteers (n=19 High-intensity Training; and n=20 BJJ) completed a series of pain tests in a laboratory setting. Pressure pain thresholds and tolerances were assessed using a handheld pressure algometer, and thermal tolerance was assessed using a cold pressor apparatus.

**Results:** The BJJ group exhibited greater tolerance on left and right for the Cold Pressor test ( $p < 0.02$ ) and also on the right side for Pressure Pain threshold ( $p= 0.002$ ) and Pressure Pain Tolerance ( $p= 0.005$ ).

**Conclusion:** The results from this study indicate that BJJ (Brazilian Jiu Jitsu) athletes have a higher threshold and tolerance to pain than high-intensity aerobic and resistance athletes, at least for the right side. The exposure of pain stimulus may provide greater increases in threshold and tolerance over and above those achieved by high intensity exercise alone.

## **1. Introduction**

Pain is one of the most frequent presenting complaints to health care professionals (Khan et al., 2012). Pain continues to be a worldwide disabling problem (Pfizer, 2013), leading to dysphoric mood states, dysfunctional behavioral patterns, sleep deprivation, and social withdrawal, as well as disability (Beverly & Swarm, 2008). Due to the indiscriminate nature of pain and its large impact on society, it may be plausible to explore avenues alternative to conventional treatment to manage and cope with pain. One such avenue is high-intensity aerobic and resistance contact exercise (such as martial arts), with its ability to decrease participants pain thresholds and tolerances (Koltyn, Wertz, Gardiner, & Nelson, 1996). However, data concerning the effects of martial arts on pain tolerance (the maximum amount of pain one may voluntarily endure) and threshold (minimum point at which the pain is sensed as pain) remains ambiguous (Koltyn et al., 1996; Koltyn & Arbogast, 1998).

Athletes living with minor or major injuries while continuing to practice or play with pain is common and to be expected in many sports (contact and non-contact). Dirkwinkel et al., (2008) showed that athletes in general have similar pain threshold but higher pain tolerances when compared to non-athletes. The exact causes attributing to their pain tolerance differences were unknown, however, there are multiple factors which offer possible explanations to the observed pain attenuation responses in contact athletes. Pain expectancy and pain acceptance influence pain perception, with pain expectancy being the understanding that pain is inevitable in certain situations and pain acceptance as the accepting behavior and willingness to experience pain, which, for contact athletes, is a desired trait and is essential for high level performance (Dirkwinkel, Gralow, & Colak-Ekici, 2008).

Non-athletes, in comparison, may not have acquired these characteristics due to lack of exposure. Athletes also tend to have a more realistic evaluation of the meaning of pain as opposed to non-athletes. Previous exposure to pain may give contact athletes the ability to distinguish between harmful and non-harmful pain (Young, White, & McTeer, 1994). Non-athletes may not know how severe painful situations may be, leading to apprehension and decreasing their tolerance to pain. Koltyn (2000) proposes that athletes have higher pain tolerances due to greater exposure to physical training and increased fitness, resulting in higher levels of circulating opioids. As part of athletes training and performance they discover limits

to extreme physical activity and pain experience, providing a greater perception of control over the pain-physical activity interface (Deroche, Woodman, & Stephan, 2011).

It is known that high intensity aerobic and resistance exercise (as in martial arts) increases pain tolerance and thresholds, however, literature on the involvement and extent of pain attenuation in response to the contact factor remains limited. The underlying mechanisms for pain perception alterations remains unclear. This provides an opportunity to undertake experimental tests to determine whether it is the contact and threshold exposure which is leading to pain adaptations, or purely the high intensity aerobic and resistance exercise.

Brazilian Jiu Jitsu (BJJ) martial artists will be selected (contact group) and compared to other high-intensity aerobic and resistance non-contact athletes, who will form the control group. BJJ, as a martial art, has as one of its primary purposes the goal of subduing an opponent or forcing an opponent to surrender (Tap out). This is achieved through the use of various attacks and submission holds. A submission hold is the equivalent of a checkmate in the sport, reflecting a disadvantage to the opponent which would be very difficult to overcome in a fight (Gracie et al., 2001). Such attacks include joint locks, body throws to ground an opponent, suffocation with the use of chokes, or the causation of general overall discomfort. Consequently, BJJ athletes are constantly being exposed to their pain tolerance, which means to achieve a high level in the sport, the participant must learn to tolerate increased levels of pain (Gracie et al., 2001). In BJJ, it is also necessary to attain a respectable level of cardiovascular fitness, which is attainable from training alone. This is achieved through regular short and intense bouts of combat which often requires maximum strength, cardio, and mental output. This relates closely to high-intensity aerobic and resistance training, which has been refined to form a sport in itself (CrossFit). Both CrossFit and BJJ athletes engage in short intense bouts of high-intensity, aerobic and resistance exercise, however, contact is one of the main dividing factors between the two sports. In an attempt to better understand pain in an athletic population and some of the attributes of contact and non-contact athletes, this study is comparing pain tolerance and thresholds between BJJ athletes and high-intensity aerobic and resistance athletes who train to a similar intensity.

## **2. Methods**

### *2.1. Participants*

Participants (39 males) were selected from four Jiu Jitsu clubs (n=20) and one of four high performance exercise facilities in the Auckland region (n=19). This was the minimum sample size necessary (achieved through power analysis) to reasonably calculate an effect size and to minimize the false positive rate. The individuals who agreed to participate were screened by a single examiner for the inclusion and exclusion criteria. This helped to ensure the same screening process was used for each participant. Each club was approached by the primary researcher at the end of a training session (advanced class only) to ensure all participants were still present. The managers and members of each club were supplied with an information sheet, providing them with information and requirements for the following research project. The control group consisted of athletes from a high intensity, contact free, aerobic and resistant sports (H.I. Training), and were selected if they met the following selection criteria. Males only, between the ages of 18-40 were assessed to limit variability between participants (anatomical and hormonal differences) (Sato et al., 2013; Chersterton et al., 2003). All participants in both groups ranged between 60-100kg with the exception of one 106kg outlier in the control group.

#### *2.1.1. Inclusion criteria*

- Between the age of 18 and 40 to ensure full bone growth without the risk of age related degenerative changes.
- Attend an advanced BJJ class at least 2 times per week over the previous 6 months (BJJ group)
- Attend/perform other high-intense exercise regimes (such as CrossFit) at least 2 times per week over the previous 6 months (control group).

### *2.1.2. Exclusion criteria*

- Any current pain.
- Any current pathology or trauma that may alter their pain tolerance and threshold.
- Receiving manual therapy or treatment on weekly or fortnightly basis.
- Taking medication which can affect the musculoskeletal system and pain tolerance (Such as corticosteroids and analgesics).

All participants received an information sheet outlining the requirements of participation and could discuss details with the primary researcher. All participants gave written informed consent and the study received ethics approval from the Unitech Research Ethics Committee.

## *2.2. Instruments and Procedures*

### *2.2.1. Electronic Pressure Algometer*

Pressure pain threshold and tolerance values were gathered using hand-held algometry. The contact disc of the algometer was 1cm in diameter, as recommended by Vaughan et al (2007), and was placed 15cm inferior to the tibial tuberosity on the medial boarder of the tibia. The force was applied at a rate of 30 kilopascals per second (kPa/s). Pressure was applied through the participant PPT (minimum point at which the applied pressure is sensed as pain) until their pressure pain tolerance was reached (the maximum amount of pressure one may voluntarily endure), or the electronic algometer reached its max value at 2090 kPa.

The hand-held pressure algometer used in this study (See Figure 1) was a Somedic Algometer Type 2, Sweden. The electronic display shows the pressure readings and has options to change the units at which force is measured (being kilopascals – kPa). The threshold and tolerance readings were marked with the use of a stop button attached to the algometer, which when pressed, froze and saved the pressure reading. Consistency of application with the instruments is essential for data reliability and analysis. This was achieved by familiarization and constant repetitive practice at applying steady pressure at a constant rate within a certain time frame, as suggested by Chesterton, Sime, Wright, & Foster, (2007).



Figure 1. Somedic Algometer Type 2, Sweden.

The electronic display shows the pressure readings measured (being kilopascals – kPa), used for measuring pressure pain threshold/tolerance.

Participants were positioned in a supine position on a treatment table and directed to wear shorts to enable direct access to skin. To avoid contact with tendons, muscles and bursa, the disc of the pressure algometer was placed 15 cm inferior to the tibial tuberosity in the center of the medial boarder of the tibia. Force was applied perpendicular to the tibia. Each participant, for the pressure pain testing *and* the cold apparatus, was directed to indicate when they first experienced the sensation change from pressure to pain with the word ‘pain’. This was the first reading recorded for their pressure pain threshold. Force was continually applied until the participant said ‘stop’, at which point the participant pushed the stop button and the pressure algometer was removed. This recorded the final reading on the digital screen, noting the participant’s pressure pain tolerance. This procedure was repeated for all 40 participants.

### 2.2.2. Cold pressor apparatus

The cold pressor apparatus is essentially a narrow bucket of cold water with a circulation device at the bottom to prevent warm water from gathering around the participants’ hands. Participants submerged both hands (one at a time) in the apparatus which stimulates thermal nociceptors. Water temperature was kept between 0.5-1 degrees Celsius, which is believed to mimic the effects of chronic conditions due to its unpleasant sensation (Mitchell, MacDonald, & Brodie, 2004), and provides a high level of reliability (Edens & Karen, 1995).

Temperature consistency was achieved with the use of a thermometer before and during each individual test. The addition of ice was added as necessary to maintain 0.5-1 degrees Celsius. Measurement indices were 1) Pain threshold time (the point at which pain is first experienced) and 2) Pain tolerance time (the maximum amount of pain tolerated). Both of which are measured in seconds with a stopwatch. Cold pressor testing was conducted individually. Thresholds were the first readings recorded for the thermal pain data, followed by tolerance readings. The participant was instructed as follows: 'Place your hand in the device up to your wrist. Without removing your hand, you must then say the word 'pain' when you first experience the sensation of pain. Following this, keep your hand in the water for as long as you can tolerate the pain and then remove your hand'. The first reading (threshold) is recorded when the participant says the word 'pain' and the second reading (tolerance) is recorded when the hand is removed from the water.

Participants maximum experimental time was limited to 5 minutes, to avoid any potential tissue damage or prolonged pain. Keeping the temperature above 0 degrees ensured participants would not be exposed to tissue freezing temperatures (Mitchell 2004).

Statistical analysis was run using SPSS v.22 software. Shapiro-Wilk tests were used to explore normality of data. Between group differences were explored using independent samples t-tests. Significance was set at  $p < 0.05$ . Unless otherwise stated, values are reported as mean (SD).

### **3. Results**

A laterality effect was observed for Pressure Pain Threshold (KPa) (Left = 712(349), Right=797(340),  $t = -2.99$ ,  $p = 0.005$ ) and for Pressure Pain Tolerance (Left = 1431(438), Right=1543(432),  $t = -2.40$ ,  $p = 0.021$ ), however no laterality effect was observed for Cold Pressor Tolerance (s) (Left = 221(76), Right=225(69),  $t = -0.89$ ,  $p = 0.38$ ). Subsequently, sides were not pooled for analysis.

A significant difference was observed on both sides between groups for Cold Pressor Tolerance (See figure 2) (Left: BJJ = 251(53), H.I.Training = 190(86),  $d = 0.80$ ,  $t = 2.66$ ,  $p = 0.013$ ; Right: BJJ = 251(50), H.I.Training = 199(78),  $d = 0.75$ ,  $t = 2.476$ ,  $p = 0.019$ ). A significant difference was observed on the right side for Pressure Pain Threshold (See figure 3) (BJJ = 954(383),



H.I.Training = 633(182),  $d= 0.95$ ,  $t= 3.37$ ,  $p= 0.002$ ) and Pressure Pain Tolerance (see figure 4) (BJJ = 1728(409), H.I.Training = 1348(375),  $d= 0.88$ ,  $t= 3.02$ ,  $p= 0.005$ ). However, there was no significant difference between the left side for Pressure Pain Threshold (BJJ = 817(367), H.I.Training = 603(300),  $d= 0.61$ ,  $t= 1.99$ ,  $p= 0.055$ ) and Pressure Pain Tolerance (BJJ = 1544(473), H.I.Training = 1314(374),  $d= 0.53$ ,  $t= 1.70$ ,  $p= 0.101$ ).

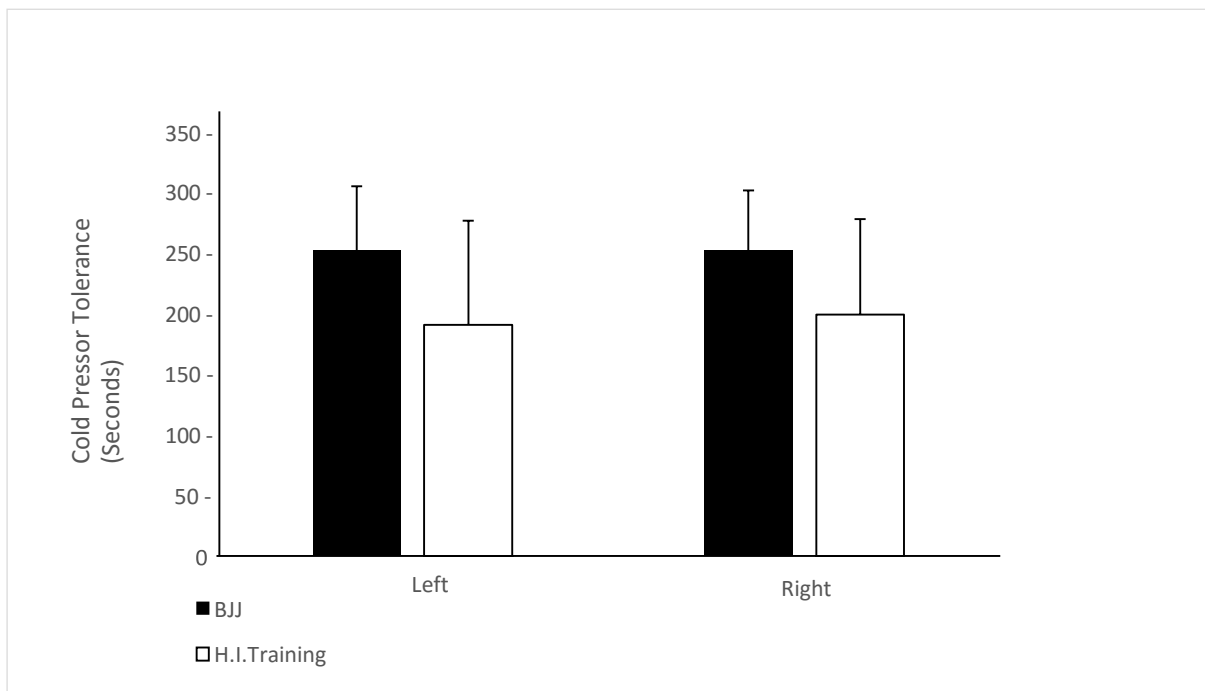


Figure 2. Cold Pressor Tolerance

A comparison of differences in thermal pain tolerances between Brazilian Jiu Jitsu (BJJ) athletes and high intensity non-contact athletes who train to a similar intensity. Error bars represent Standard deviation (SD).

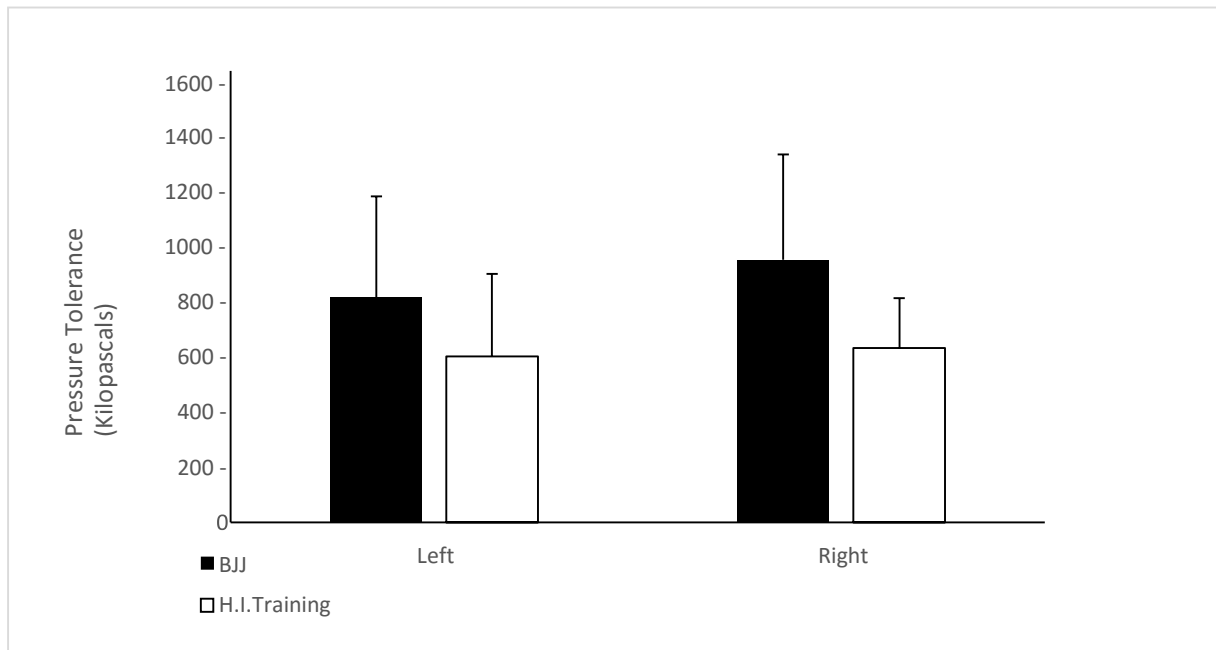


Figure 3. Pressure threshold

A comparison of the differences in pressure threshold between Brazilian Jiu Jitsu (BJJ) athletes and high intensity non-contact athletes who train to a similar intensity. Error bars represent Standard deviation (SD).

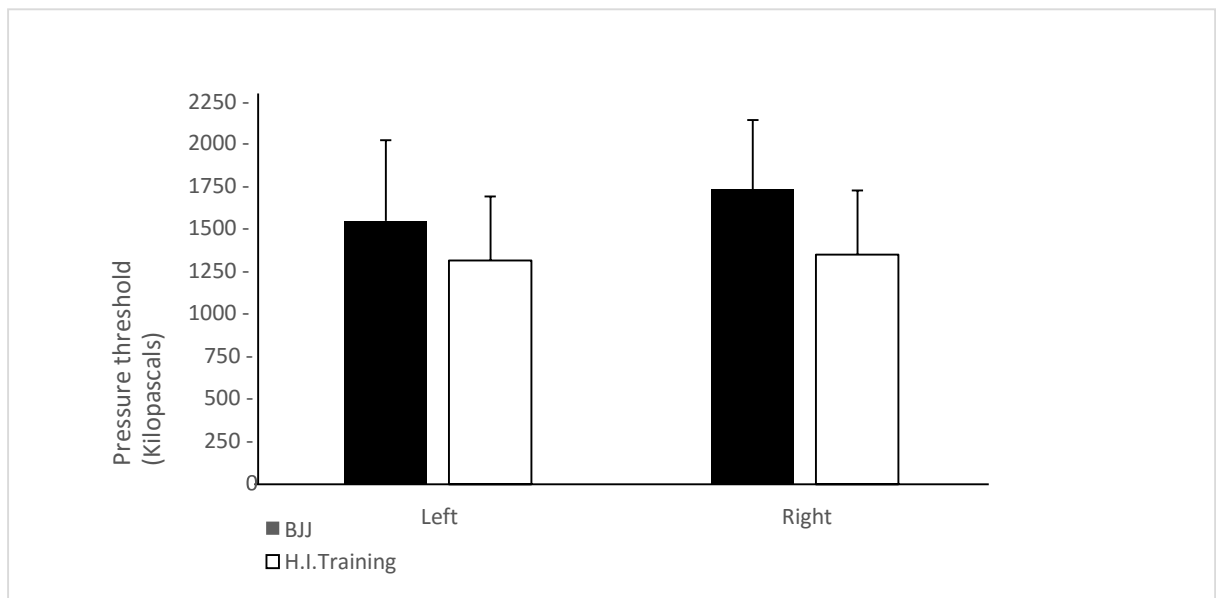


Figure 4. Pressure Tolerance

A comparison of the differences in pressure tolerance between Brazilian Jiu Jitsu (BJJ) athletes and high intensity non-contact athletes who train to a similar intensity. Error bars represent Standard deviation (SD)

#### **4. Discussion**

The results from this study indicate that the BJJ athletes included in this study have a higher threshold and tolerance to pain than the compared high-intensity athletes, at least for the right side. This is similar to empirical evidence and previous studies (Dirkwinkel et al., 2008; Focht et al., 2000) claiming that martial arts participation may temporarily change participants perception of pain and raise pain tolerance. A point of interest was to see if the results of the present study would build on to those by Focht et al (2000) and Dirkwinkel et al (2008), who reported higher pain tolerance levels in martial artists when compared to non-contact controls. Focht et al (2000), however, lacks information regarding which type of martial art was utilized in their study, consequently, making it hard to associate tolerance adaptations to contact, and Dirkwinkel et al (2008) compares already conditioned Kung Fu students with non-conditioned 'healthy active individuals'. Comparing the efficacy of BJJ against another training modality identifies if the exposure to physical pain during BJJ creates a different adaptation than to discomfort, experienced in similar exercise modalities known to physically condition individuals.

Although it is plausible that individuals who possess a higher pain tolerance are more likely to select BJJ as a sport. Dirkwinkel et al., (2008), and Focht et al., (2000) have identified a correlation between martial arts and pain tolerance differences which may be linked to martial art participation itself. However, there is little research investigating a causal link. Regardless, it remains reasonable to consider the difference between groups as, at least in part, an effect of participation in a contact modality (such as BJJ), rather than the cause. Future longitudinal studies may be beneficial in determining the underlying cause of the pain adaptations observed in martial arts athletes. This would also help to solidify the claims made by Dirkwinkel et al (2008) and Focht et al (2000) that martial arts participation may lead to pain habituation.

Pain threshold and tolerance differences between groups were observed. The source and reason for tolerance differences remains unclear, however, results may be explained by physiological nociceptive adaptations involving receptor and hormone regulation in response to pain stimulation and exposure (Dirkwinkel et al., 2008; Pauli, Wiedemann, & Nickola, 1999; Thoren, Floras, Hoffmann, & Seals, 1990), or, more likely, psychological pain coping alterations involving the participants' cognitive appraisal of pain, which is known to influence the amount of pain actually perceived (Fernandez & Turk, 1989; Hsieh, Stone-Elander, & Ingvar, 1999; Sawamoto, Honda, & Okada, 2000). This occurs through familiarization, confidence, and technical knowledge. Whatever the source may be, a clear difference in pain tolerance is evident.

Pain threshold alterations may be linked to the phenomenon of pain habituation, which occurs when repeated stimuli elicit progressively smaller nociceptive pain responses over time (Glaser & Griffin, 1962), however, due to the cross-sectional design of this study, it is impossible to identify if threshold differences are owing to pain habituation. Pain habituation has been previously reported in martial arts (Dirkwinkel et al., 2008; Focht et al., 2000) and high intensity aerobic and resistance exercise (K Koltyn, 2003; KF Koltyn & Arbogast, 1998), and was expected to be more prevalent in the BJJ group in the present study. Vierch, Staud, Price, & Cannon (2001) provide an explanation of habituation resulting from high intensity exercise, revealing that noradrenergic and opiate systems activate in response and in proportion to the intensity and length of exercise. However, due to the lack of painful stimuli noted to activate this mechanism in the Vierch (2001) study, the pain threshold adaptations in Vierch (2001) are likely accompanied by another mechanism. Of which may be responsible for the analgesic effects producing pain tolerance adaptations. These adaptations were not apparent in the control group.

Although it is unclear as to the exact cause of high tolerance levels in BJJ athletes, it is reasonable to suggest that psychological pain coping strategies involving the participants' cognitive appraisal of pain are heavily involved, supporting earlier research suggesting cognitive conditioning can alter pain appraisal and in turn pain tolerance (Ehde, Dillworth, & Turner, 2014). An example of this is graded *in vivo* exposure (Woods & Asmundson, 2008) and Cognitive Behavioral Therapy (Ebert & Kerns, 2010) which can lead to improvements in measures which effect an individuals' ability to tolerate pain. These measures include fear of pain/movement, pain-related anxiety, fear avoidance beliefs, and pain self-efficacy, and have been compared to other therapies through which they have proven to be more effective (Woods & Asmundson, 2008; Ebert & Kerns, 2010). These are examples where cognitive conditioning has been applied, consequently proving to be an effective protocol in the treatment of pain.

Comparatively, endurance athletes have a conditioned cognitive appraisal to pain, indicating that the ability to 'push past' and tolerate prolonged discomfort accounted for much of their success (Whitmarsh & Alderman, 1993). Similarly, in BJJ, this heightened ability to tolerate pain through constant exposure and conditioning also exists, however, unlike endurance athletes, the pain stimulus applied to BJJ athletes is in short-intense bouts (1-10 seconds), raising the likelihood that pain adaptations will be different in these athletes. This occurrence is likely to involve the athletes' appraisal of pain and their ability to analyze the level of threat; learning that pain is not

necessarily harmful, but an essential part of the sport; giving them the ability to endure what they know will and will not harm them, through experience and constant application (Deroche, Woodman, & Stephan, 2011). In BJJ, the goal is to make your opponent “tap out” and pain exposure occurs through the application of painful submission chokes, joint locks, and pressure attacks (Gracie et al., 2001)

Increased fitness, endorphin release, learning self-defense and increased self confidence levels are all positive outcomes which result from BJJ participation (Gracie et al., 2001). These outcomes warrant the exposure to non-harmful pain and can lead to athletes changing their appraisal of pain from “negative” to “neutral”, accepting it as an inevitable aspect of the sport. To the BJJ athlete, there are many alternative responses they may choose to make as a result of pain, as they are unlikely to dwell on pain and its potential negative connotations, but rather, use it as a valuable indicator to guide their strategy. This point is relevant as it provides evidence of a potential dose response occurrence (Dose = exposure to pain tolerance in BJJ. Response = pain perception differences) and evidence of adaptation to pain in a pleasant context (unlikely to dwell on pain and push through to overcome unpleasant sensation). This concept may potentially be utilized to inform management strategies for central sensitized and chronic pain sufferers.

A noticeable variance between left and right sides of the body was evident for pressure pain thresholds and tolerances (all 39 participants were right hand dominant), which correlates with some laterality effects found in previous studies, suggesting an association to handedness (Pauli, Wiedemann, & Nickola, 1999; Pud, Golan, & Pesta, 2009). The psychology and physiology behind this phenomenon remains unknown, however, it may be possible that handedness leads to physiological changes, more so than psychological, suggesting preference and exposure of the dominant hand may lead to increased threshold over non-dominant hands. These differences do not appear to be pressure-specific. This means that although BJJ athletes are often exposed to pressure and joint pain, the effect was also noted for temperature tolerances. This means the adaptations occurring from frequent pain exposure is occurring higher up than local nociceptors (Rysewyk, 2013).

Unlike pressure-pain laterality effects, no handedness effect was noted for the cold pressor testing. Similar reports of uniformity have been made by Pud, Golan, & Pesta (2009) who investigated the contribution of handedness and gender to sensitivity to tonic cold pain in healthy subjects. 109 Participants (both male and female, 65 were right-handed and 44 left-handed) were exposed to the cold pressor test (1-degree Celsius) for both hands while measuring the cold threshold, intensity, and tolerance. No significant differences were found between the left versus the right hands among both the right-handed and left-handed subjects. This may be owing to equal exposure in left and right sides of the body to temperature extremes, consequently leading to even thermoreceptor adaptations on left and right sides of the body. No further investigation into handedness was applied, as it remains out of the scope of this study.

#### *4.1. Limitations*

The design of the study means that difference between groups needed to be conservatively discussed. It was not possible to identify adaptations or habituation owing to BJJ participation through a cross-sectional study. With more time, a longitudinal study would have been the selected design to discover if the observed differences were owing to participation in BJJ. Another limitation was participant recruitment. It was difficult to find participants who had either CrossFit or BJJ as their only weekly activity whilst remaining within the inclusion criteria. This means there could have been external factors and activities which could have influenced results. Having a greater number of participants in each group would have been valuable to further minimize false positive/negative probability and improve the reliability of the effect size.

Considering the experimental pain testing, it would have been ideal to further validate results with the inclusion of another testing protocol. The two chosen methods were the cold pressor thermal test and pressure algometry. Saline injection or electrical stimulation could have been included with preparation. Participant information was also limited. There was no mention of participants BMI, exact age (only within a certain age range), and height. These are factors which could have been included in the study, however it was unclear on how these variables could affect results and were therefore dismissed.

#### *4.2. Future recommendations*

Due to the nature of this study, it was impossible to conclude whether the people who select BJJ as a sport are naturally able to tolerate more pain (and are therefore drawn to the sport) or whether their higher threshold and tolerance levels are owing to participation. Personality, however, has been recorded as an influential factor in the selection of contact sports, with more aggressive people selecting training styles that are consistent with their needs (Sohrabi, Atashak, & Aliloo, 2011). Anecdotally, BJJ novices appear to learn to tolerate pain as they become more experienced, however empirical evidence of this is lacking. It would be beneficial to conduct a randomized controlled trial with randomization of participants into alternate training protocol groups, thereby removing the likelihood that naturally higher pain tolerant people would congregate in the BJJ group. The results from this study provide support for exploring pain habituation in a longitudinal study, which may provide an additional mechanism in this regard. Considering habituation, it may be plausible to further investigate the utility of habituation as a form of pain therapy.

#### **5. Conclusion**

It may now be plausible that some of the pain adaptations and habituation phenomena observed in sporting and experimental studies are also occurring in the martial art of BJJ. Data suggests that BJJ participants have different pain adaptations than a comparatively high intensity aerobic and resistance, non-contact exercise group. It was interesting to see that pain tolerance levels were significantly higher in BJJ athletes than the control group who also engaged high-intensity aerobic and resistance training. Both groups partake in high-intensity aerobic and resistance training. These ‘type’ of exercise protocols are very similar, minus the contact aspect. This data remains open to interpretation; however, one could speculate that there may be a dose-response link between the amount of pain an athlete is exposed to and pain tolerance adaptations, allowing for the observed tolerance differences between groups in this study. Just as interesting was the difference in pain thresholds observed, which prior research has not found. This difference may be owing to the phenomenon of pain habituation, occurring when repeated stimuli elicit progressively smaller nociceptive pain responses over time, as witnessed in BJJ.

This research is a step towards understanding pain threshold and tolerance differences in both contact and non-contact, high-intensity aerobic and resistance athletes. Exposure to contact pain appears to correlate directly with higher pain tolerances than commensurate athletes who train to a similar intensity and frequency. We must note that it remains plausible that people with higher pain tolerances and thresholds are more likely to participate in painful sports and actively seek out sports to satisfy their needs. Future research should confirm if the observed changes were caused by the frequent exposure to painful stimuli.



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## **Section III: Appendices**

Vance Miller  
232 Glenvar Rd  
Torbay  
Auckland

19.2.15

Dear Vance,

Your file number for this application: **2014-1112**

Title: **Do BJJ athletes have different pain thresholds and or tolerances to experimental pain, when compared with commensurate groups of cross-fit athletes?**

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

**Start date: 19.2.15**

**Finish date: 19.2.15**

Please note that:

1. The above dates must be referred to on the information AND consent forms given to all participants.
2. You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC.

We wish you every success with your project.

Yours sincerely,



Sara Donaghey  
Deputy Chair, UREC

cc: Jamie Mannion  
Cynthia Almeida



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## Appendix A: Information sheet for participants



### RESEARCH INFORMATION FOR PARTICIPANTS

You are invited to participate in our research investigation. Please read carefully through this information sheet before you make a decision about volunteering.

#### Research question

Do BJJ athletes have different pain thresholds and or tolerances to experimental pain, when compared with other high-performance athletes?

#### Researcher

My name is Vance Miller and I am a Master of Osteopathy student at Unitec New Zealand. As part of this programme I am conducting a research project.

#### Purpose of the study

The purpose of this investigation is to determine whether participation in martial arts (in particular Brazilian Jiu Jitsu) is associated with greater increases in pain thresholds and decreased pain ratings when compared to non-contact, high intensity aerobic exercise.

#### What the study involves

Taking part in this study will require you to attend one sessions at AUT's Akoranga campus. Each session will last approximately 30 minutes. During the study you will be asked to sit down at a table, from where a pressure algometer (small device used to apply pressure) will be applied to the anterior medial boarder of the tibia. The pressure will be applied until your pain tolerance is reached, then the pressure device will be removed. Following the pressure device, you will be asked to put your hand in cold water to test your hypothermic tolerance. You will be asked to keep your hand in the cold water for as long as tolerable. This is described in more detail below.

#### About the experimental pain

The experimental pain conditions (hypothermic and pressure) can be expected to produce an intensity of approximately >5/10 and will begin to subside immediately after contact with the devices stops. The perceptual characteristics are most commonly described as 'aching', 'cramping', and 'dull' for the cold apparatus (cold water), and 'pressure', 'sharp' for the pressure Algometer.

Adverse reactions are extremely rare and may consist, bruising or an undesirable level of pain. Excessive pain may be alleviated quickly by applying ice to the painful (pressure pain area), and putting your hand in luke warm water (thermal pain). If you would like us to contact your GP prior to your participation, please provide their contact details below:

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For immediate and after-hour concerns, you may contact an A&E clinic. The most local clinics that are open 24 hours are Ascot White Cross, contact number 520 9555 and Henderson White Cross, contact number 836 3336. Participants will be observed for 20 to 30 minutes following the pressure algometry and hypothermic pain, by which time the experimental pain should have almost completely subsided.

If required, counselling services are available at Unitec, Mt. Albert campus for all Maori and non-Maori Unitec students and staff. Contact number: 815 4321, extension 7248. Maori consultation services are also available (Hare Paniora, Phone 815 2934)

### **Your voluntary participation**

Your participation in this study is entirely voluntary and you may withdraw at any time during the practical procedures. Data collected from your involvement in the study may be withdrawn up until 1 week following data collection.

### **Who may participate?**

#### **You are eligible to participate if you:**

- Between the age of 18 and 45 to ensure full bone growth without the risk of age related degenerative changes.
- Attend BJJ or CrossFit training an average of at least 2 times per week over the previous 6 months.

#### **You are not eligible to participate if you:**

- Any current pain.
- Any current pathology or trauma that may alter their pain tolerance and threshold.
- Currently receiving manual therapy or treatment on a regular basis.
- Taking medication which can affect the musculoskeletal system and pain tolerance.

Please inform the researcher if any of the above pertains to you.

### **What we do with the data and results, and how we protect your privacy.**

Personal information is collected and stored under the guidelines provided by the Privacy Act 1993 and the Health Information Privacy Code 1994. For information collection your identity will remain anonymous and you will simply have an identification number. If the information you provide is reported or published, this will be done in a way that does not identify you as its source. All the data recorded will be stored in password-locked computers and archived in a locked file room and will be stored for a minimum of 5 years. Access to this data will be limited to the researchers involved and yourself. This research project is not sponsored by any commercial company. This research project is part of Master of Osteopathy Program.

## **Compensation for Adverse Reactions**

Compensation may be available in the unlikely event of injury of negligence. As this procedure can be defined as a treatment, you may be eligible for compensation for treatment injury as described under Accident Compensation Act, 2001. Should you incur a physical injury as a result of your participation in this study, you may be covered by ACC under the Injury Prevention, Rehabilitation and Compensation Act 2002. You may or may not be entitled to ACC compensation, depending on several factors such as whether or not you are an earner. ACC will usually cover a proportion of income lost due to a physical injury, this does not cover mental injury unless as a direct result from a physical injury. ACC cover may affect your right to sue. Please contact your nearest ACC office for further information (0800 735 566) or visit their website: [www.acc.co.nz](http://www.acc.co.nz)

A summary of the final report will be available to you if you are interested.

Please contact me if you require further information about the study.

Principal investigator

Supervisor Jamie Mannion

Vance Miller

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Email: [vmiller.m@hotmail.com](mailto:vmiller.m@hotmail.com)

This study has been approved by the Unitec Research Ethics Committee 2014-1112 from 19.02.15 to 19.02.15. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (Ph: 09 815 4321 ext.7254). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.



## Appendix B: Participant consent form



### Participant Consent Form

**Do BJJ athletes have different pain thresholds and or tolerances to experimental pain, when compared with other high-performance athletes?**

**I have had the research project explained to me and I have read and understand the information sheet given to me.**

I understand that I don't have to be part of this if I don't want to and I may withdraw at any time up to two weeks after receipt of the transcript.

I understand that I will be subjected to clinically induced hypothermic and pressure pain. I understand the possibility of an adverse reaction to the clinically induced pain.

I understand that everything is confidential and none of the information I give will identify me and that the only persons who will know what I have said will be the researcher and their supervisors. I also understand that all the information that I give will be held in a secure location if printed or password controlled if electronic for a period of 5 years.

I understand that I can see the finished research document.

I have had time to consider everything and I give my consent to be a part of this project.

*Participant Name:* ..... *Date:* .....

*Participant Signature:* ..... *Date:* .....

*Project Researcher:* ..... *Date:* .....

**UREC REGISTRATION NUMBER: (2014-1112)**

**This study has been approved by the UNITEC Research Ethics Committee from (19.02.15) to (19.02.15). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.**



Full name of author: Vance Miller

ORCID number (Optional): .....

Full title of thesis/dissertation/research project ('the work'):

An investigation into pain threshold and tolerance differences between Brazilian Jiu Jitsu athletes and a commensurate group of high-intensity training, aerobic and resistance athletes.

Practice Pathway: .....

Degree: Master of Osteopathy

Year of presentation: 2017

Principal Supervisor: Jamie Mannion

Associate Supervisor: David Rice

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Signature of author: V. Miller

Date: 14.1.2017



## Declaration

Name of candidate: Vance Miller

This Thesis/Dissertation/Research Project **entitled** : An Investigation into pain threshold and tolerance differences, between Brazilian Jiu Jitsu athletes and a commercial group of high-intensity training, aerobic and resistance athletes. is submitted in partial fulfillment for the requirements for the Unitec degree of Master of Osteopathy

Principal Supervisor: Jamie Mannion

Associate Supervisor/s: David Rice

### CANDIDATE'S DECLARATION

I confirm that:

- This Thesis/Dissertation/Research Project represents my own work;
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: .....

Candidate Signature: Vance Miller Date: 10/12/17

Student number: 1347446