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Efficacy of pain scales in athletic populations and paired with aglometric measurements

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EFFICACY OF PAIN SCALES IN ATHLETIC POPULATIONS AND PAIRED WITH ALGOMETRIC MEASUREMENTS

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ABSTRACT

Objective: Pain is the most common symptom and reason for why affected individuals seek out medical attention for injuries. The most common pain scales are: the numerical rating scale (NRS), 5-point verbal rating scale (VRS-5), and visual analog scale (VAS) but there is no gold standard established to measure unidimensional pain intensity. Algometry is an objective technique to measure pain pressure threshold and tolerances. However, there is little research on which scale is best suited to assess pain intensity in different demographics; including athletic populations and other types of groups; as well as, whether subjective pain scale measurements can be correlated to objective algometric measurements.

Methods: Both men and women between the ages of 18-35 with joint pain were recruited to participate in the study. The four common pain scales (NRS, VAS, VRS-5 Mankoski) as well as patient specific functional scale(PSFS), brief resiliency scale(BRS), and pain catastrophizing scale (PCS) were completed by each subject. Then each participant had their pressure discomfort threshold (PDT) and pressure pain tolerance (PPT) tested with an algometer at 3 pre-determined sites as well as where the subject had joint pain, bilaterally. Data was analyzed and sorted into subgroups: National Collegiate Athletic Association (NCAA) Division I athletes and non-collegiate athletes, men and women, injured and non-injured.

Results: Participants (n=69) completed the study, all of the pain scales were consistently correlated together in every subgroup of data (collegiate athlete vs non-collegiate athlete, men and women, injury status). The pain scales were not consistently

correlated to any of the algometric measurements. Collegiate athletes rated their pain higher than non-collegiate athletes using the NRS. There were no statistically significant differences between genders, but men consistently tolerated more force when applied during algometry measurements. The individuals, who identified as injured, had higher pain ratings on pain scales but tolerated a similar amount of force applied when the algometry measurements were taken.

Conclusion: NRS, VAS, VRS-5, Mankoski scales could all be used to assess the pain intensity of athletes or the athletic population. Clinicians should be aware that NCAA Division I collegiate athletes have higher pain thresholds and pain tolerances compared to non-collegiate athletes.

Key words: pain threshold, pain tolerance, algometry, NRS, VAS, VRS-5, Mankoski.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

I Introduction

Pain is a part of life, experienced by all, and is one of the most common patient complaints in healthcare and has been studied in the medical field for hundreds of years[1-6]. However, pain perception is complex with various neurological processes and can be significantly impacted by a multitude of different factors[7-11]. Pain is also subjective, varying greatly among individuals. While there has been extensive research into pain and pain assessment, there is no specific gold standard of how to assess unidimensional pain intensity[10,12-17]. Each self-rated pain scale subjectively assesses pain intensity differently and consequently has differing advantages and disadvantages[18-20] The most common pain scales utilized for self-reported pain intensity are the: numerical rating scale (NRS), verbal description scale (VDS), and visual analog scale (VAS)[18,21-26]. All of those pain scales have been well investigated regarding efficacy of use with the general population and in some sub-populations such as chronic pain patients[18,19,24-28]. A sub-population that has not been thoroughly investigated is the active population including both competitive athletes and recreationally active individuals. There is a consensus within the literature that people within the active population, like athletes, have higher pain thresholds and pain tolerances[29]. However, there is little pain scale research regarding which scale is best suited for assessing pain intensity in athletic or active populations.

Due to the inherent flaws with subjective assessments of pain, the most notable being the variation in perception between individuals, attempts at objectively quantifying pain ratings have been made[14,30-34]. A potential objective technique to

measure pain is with the use of an algometer, a device that measures the amount of force needed to reach an individual's pain pressure threshold. The current literature demonstrates that the use of algometers in clinical settings is quite feasible due to low cost and minimal training required to complete algometric measurements[35-40]. Previous studies have also indicated valid and reliable measures when using multiple different anatomical sites[35,37,38,41,42]. Additionally, algometric measures have been demonstrated to have high test-retest reliability[30,35,38,39,41,43-45]. In studies performed by van Wilgan et al and Kregel et al, an algometer was used to assess the progress of a pathology or current treatment plan being implemented[30,35,38,39,41,43-45]. However, there have yet to be studies that correlate algometry measurements with any pain scale ratings. It is possible that algometry measurements could be used to objectively quantify pain (and relate them to pain scale measurements) by obtaining a baseline measurement and then comparing the baseline value to post-injury values taken immediately after injury and for the duration of treatment of said injury. This process would clinically verify if self-reported pain perception provided by the patient relates to the objective pain pressure threshold thus providing clinicians a more robust understanding of individual patient pain perception and possible coping.

Although it has been reported that athletes have higher pain tolerances and pain modulation capabilities, it is unknown if the commonly used pain scales that have been studied within general population and chronic pain populations are similarly effective/accurate for athletic populations. Therefore, the purposes of this study were to determine if the pain scales used for the general population could be specific and

sensitive to the athletic population and if algometry measurements could be used to quantify pain. The hypothesis was that all pain ratings would be positively correlated to each other and the algometry measurements. The second hypothesis was that there would be overall higher pain thresholds and tolerances seen with the athletic population compared to non-athletic population.

There were several potential limitations and delimitations to the study. Since recruitment and data collection was completed on a college campus, the majority of participants were between the ages of 18 and 25. With data being collected on a smaller age range, there was a potential decrease of generalizability to older age groups from any correlations found. Since the study was partially survey-based, there was the possibility that subjects would not complete the survey truthfully, potentially skewing the data collected on pain scale measurements. By using the algometers, inter-rater and intra-rater reliability must be established if more than one clinician completes algometric data collection.

For this experimental design, the assumption was that athletes or people who are more physically active on a regular basis are going to have higher pain pressure threshold levels and tolerances. The differences between active and sedentary population thresholds and tolerance levels have been previously observed in literature[29,46]. The differences observed could be potentially due to active populations being in pain more frequently thus learning to cope with the sensation[47]. People who are physically active are more likely to have a musculoskeletal injury compared to sedentary populations due to increased exposures to high demands and loads on their

bodies. Additionally, the mentality of 'no pain, no gain' is common within the athletic population and they are more likely required to tolerate pain from physical activity like muscle soreness while continuing to maintain activities of daily living[12,47].

Definition of Terms

- Action potential - the nerve's capability to send an electrical signal
- A-delta fibers - small-diameter, highly myelinated fibers that quickly transmit stimuli information, like: mechanical pressure, extreme temperatures, and ischemic pain. When activated, individuals can feel sharp pain, usually seen with acute injuries
- Algometer - device that measures the intensity of applied pressure (N) required to elicit pain at pain threshold and pain tolerance levels
- C-fibers - small diameter, unmyelinated that are stimulated by mechanical pain, extreme temperatures, and chemicals. When activated, individuals can feel nonlocalized, dull, diffused pain
- Exercise induced hypoalgesia (EIH) – a marked decrease in sensation seen in individuals exercising, potentially due to the release of endogenous chemicals
- Neural signature – also known as neurotag or neuromatrix, is the sequence of brain structures that receive nociceptive signals and are part of the determining if stimuli is painful
- Nociception - neural processes of receiving noxious stimuli picked up by receptors throughout the body and then sending a signal regarding the stimuli collected to the brain for interpretation
- Pain threshold - the level reached when an individual begins to feel pain
- Pain tolerance - the highest level of pain tolerable by the individual

Significance of the Study

There has yet to be a study that examines how effective commonly used pain scales with the general population are for active and athletic populations. Additionally, research has yet to be conducted to determine if there is a relationship between pain pressure threshold measurements and self-reported pain levels and/or sensations. It is possible that quantification of pain in the clinical setting may provide further information for individualized patient care.

II Research

Pain

Nociception is the neural processes of receiving noxious stimuli picked up by receptors throughout the body and then sending a signal regarding the stimuli collected to the brain for interpretation[7]. The interpretation of stimuli is a process that can be broken down into three parts – alert, message, and response[7]. There are a multitude of different types of nerve receptors throughout the body which respond and activate to different stimuli. Every receptor is attached to a corresponding nerve. An alert is any kind of stimuli that is picked up by receptors and so triggers a normal neural response. When the nerves become activated by the stimulated receptors, an action potential (the nerve's capability to send an electrical signal) is generated and fired, which carries the alert along the nervous system to the brain as a message. A-delta and C fibers are the afferent (sensory) nerve fibers that transmit signals to the dorsal horn of the spinal cord which gets further relayed to the cerebral cortex. From the cerebral cortex, the message is analyzed and interpreted as either painful or non-painful stimuli. If it is classified as painful, the brain then determines if the body is either in danger or not, which dictates the type of response to the potentially painful stimuli[7].

A-delta fibers are small-diameter, highly myelinated fibers that quickly transmit stimuli information, like mechanical pressure, extreme temperatures, and ischemic pain[7]. When A-delta fibers are activated, the response the individual feels is a sharp pain, as seen with acute injuries[7]. C fibers are small diameter, unmyelinated fibers

that are stimulated by mechanical pain, extreme temperatures, and chemicals. C fibers are the most abundant type of nerve fiber in the body and their purpose is to monitor the body for potential problems which is why it can be activated by many different types of stimuli[7]. Different chemicals produced by the body either routinely or in response to stimulation can cause different effects on C fibers. Bradykinins and histamines directly stimulate C fibers while prostaglandin increases the sensitization of nerve fibers and increases the nociceptive impact of other mediators. Substance P is a neurotransmitter that produces pain response, peripherally produces hyperalgesia, and inflammatory responses[7]. When C fibers are activated from stimuli, the individual may feel the response of nonlocalized, dull, diffused pain[7].

For the nociceptive signal to be sent from the activated A-delta fibers or C fibers, the level of noxious stimulus must be strong enough to reach the individual's pain threshold which when reached generates and fires an action potential[7]. Once the stimulus reaches the pain threshold, the message is sent through the dorsal horn of the spinal cord, past the interneuron block and is then passed along to the cerebral cortex via second order neurons. The nociceptive signal is received and bounced to several different parts of the brain where it is interpreted then as pain[3]. The different order of which parts of the brain receive and send the nociceptive signal creates a neural signature, sometimes referred to as pain neurotag, neuromatrix, or map[3]. It is postulated that this so-called matrix exists in order for the brain to quickly determine if the signal from the stimulus poses a danger to the individual possibly leading to harm (physical and/or psychological). If the individual's perception is that danger is present,

and harm may occur, then their fight or flight response may occur. The fight or flight response causes the release of epinephrine to allow the individual to escape or defend from the painful stimulus. The brain could also determine that there is not a threat or danger and release endogenous, inhibitory chemicals to modulate the nociceptive signal being sent from the activated A-delta and C fibers[3]. Conversely, there are a variety of different endogenous inhibitory chemicals produced by the body used to decrease pain perception including opioids, enkephalins, endorphins, and serotonin[3].

In chronic pain patients, it has been observed that their nerves become more sensitized and have an increased excitability resting rate (or a decreased threshold) which results in the need of less stimuli to reach the same pain threshold to fire an action potential. In other words, it takes a much smaller amount of stimulation for a person in chronic pain to perceive a stimulus as potentially or actually harmful compared to an individual without pain. The increased rate of nociceptive signals activating A-delta and C fibers results in a faster and more sensitive neural signature and a decreased pain modulation ability[3], thus creating more perceived pain sensations for the individual.

With more active populations, there is an increased risk for musculoskeletal injury during activity. Active people are more likely to endure pain from injuries with differing significance but have a very different pain perception than in chronic pain patients. In the athletic population, the difference could potentially be explained due to a different type of neural signature formed where the brain does not perceive the nociceptive signals as pain and releases nociceptive-inhibition chemicals earlier as a

result of an adaptation to consistent exercise. The release of such endogenous, inhibitory chemicals is associated with exercise-induced hypoalgesia (EIH) and attributed to how athletes can keep performing after being seriously injured[29]. However, the concept of EIH is not fully understood and needs additional research. With some studies, there has also been significant increased pain tolerance and pain threshold levels within athletic populations when compared to normal active controls[29]. The differences in pain tolerance and threshold signify how the athletic population differs from general population and so may change the efficacy of how clinicians measure and assess pain with active populations.

Pain Scales

Pain is the most common complaint clinicians hear about and has been referred to as an additional vital sign[7]. Although pain is the most common patient-reported symptom, assessing pain has not been completely standardized. Currently, there are many different unidimensional pain scales that measure pain intensity including the Visual Analog Scale (VAS), Numerical Rating Scale (NRS), Verbal Rating Scale (VRS)/ Verbal Description Scale (VDS), or FACES Pain Rating Scale[22]. While all unidimensional pain scales measure pain intensity, each pain scale is different and assesses pain intensity differently.

The VAS is a 10 cm line anchored with “no pain” and the opposite end being “worst possible pain”. The VAS is a seemingly straightforward pain scale to administer. However, in several studies, elderly and disadvantaged populations have difficulty accurately completing the scale[22,26]. Another obstacle with utilizing the VAS is that

clinician must measure and determine the score of the pain scale based on the patient's feedback[18]. Results can also be impacted by the visual orientation of the pain scale being vertical or horizontal[22].

The NRS can be utilized for rating an individual's pain level from a scale of zero to ten or zero to 100, with zero being "no pain" and the other anchor being at level 10 or level 100 being "worst pain possible". In a systematic review by Hjermstad et al., NRS had better patient compliance in multiple different sub-populations when compared with VAS and VRS[22]. Data from NRS has also been shown to be more easily analyzed for audit purposes[7]. While the scale is easily implementable, it has been found in the Douglas study that patients have difficulty assigning a number to describe their pain without some form of reference from past experience[28].

The VRS or VDS is an ordinal list of descriptive words that go from least to greatest severity. For example, in a 4-point VRS the words could be: no pain, some pain, considerable pain, and pain which could not be more severe. In another form of VRS, the 5-point version or VRS-5, the words can be: mild, discomforting, distressing, horrible, excruciating[18]. Another scale, very similar to the VRS is the FACES pain scale (FPS)[7]. The FACES pain scale is an image of several faces, from smiling to saddening or with more pain being portrayed[22]. The FPS has been suggested to use for acute pain in the pediatric population due to its ease of use and ease of comprehension with the younger population[7]. The scale has also been found to be easily translated into different languages and still be a valid measurement of pain intensity[48]. Each face is paired with a number 0-10, ascending even numbers. Each face having a

corresponding number allows for ease of use in a research context. However, since the scale goes up by even numbers, it could be interpreted to have decreased sensitivity when compared to other scales, like the NRS.

Since there are various tools to assess pain, studies have been completed comparing the feasibility, advantages, and disadvantages of each pain scale. Williamson and Hoggart, established that VAS, VRS, and NRS were reliable, valid, and practical to use. VAS had some practical difficulties the other pain scales assessed did not[49]. From analysis in multiple studies, a good correlation has been established between VAS, VRS/VDS, and NRS[22]. Jensen et al. also found that VAS and NRS were more sensitive to change and could be better to implement when measuring pain with the same patient repeatedly over the course of a longer treatment period[18]. By being aware of specific limitations of different pain scales, clinicians can choose which pain scale to utilize that is best suited pain scale in context to their specific practice.

Another pain scale that addresses some of the obstacles of other pain scales is the Mankoski scale. The Mankoski scale, developed by Andrea Mankoski, was originally developed to assess pain in endometriosis patients[28]. The pain scale is similar to NRS with each number associated with a descriptive phrase, like VRS/ VDS. The Mankoski scale was assessed as reliable and valid while being compared to VAS, NRS, and Faces pain scale. Additionally, within the population of veterans with chronic, it was the most preferred pain scale to use when describing pain[28]. However, there is a lack of research on the Mankoski scale since it has not been extensively studied.

Within systematic reviews, Tesarz et al. and Karcioglu et al., assessed the level of bias from the literature collected[22,29]. Tesarz et al. assessed studies and found levels of bias as high in four studies, moderate in eight studies, and no articles with low levels of bias[29]. In other words, all current articles identified by Tesarz et al.'s study have moderate to high levels of bias which demonstrates that the current literature and clinical applications are limited[29]. Karcioglu et al., categorized studies as high, low, and unclear levels of bias with eight, seven, and four studies falling into each category respectfully[22]. Karcioglu et al., assessed quality of evidence in grades of A through D, with twelve studies within grade B and seven studies within grade C[22]. Articles with higher level of bias or low grade of quality means that there is low generalizability of the conclusions gathered from the study. Therefore, the lack of low bias and high-grade quality evidence demonstrates the need to continue research in the efficacy of how clinicians assess pain and with what tools.

Algometry

There have been multiple studies that examine pain threshold and pain tolerance with various methodologies. Pain threshold (the level reached when an individual begins to feel pain) and pain tolerance (the highest level of pain tolerable by the individual) have been quantitatively measured by cold water, mechanical pressure, ischemic methods, electrical and heat[7,29]. These measurements are often obtained via devices used in comparative studies and in most cases require expensive, complicated equipment. A more clinically applicable and inexpensive technique to measure pain threshold and pain tolerance is through the use of an algometer, which is a device that

measures the intensity of applied pressure required to elicit pain. By applying pressure, the clinician can determine when pressure is first notes as pain (threshold) and when it is no longer tolerated (maximum tolerance level). The ability to quantify pain levels is significantly helpful in the diagnosis and treatment of pain syndromes and other diagnoses[43,50].

There are different ways to incorporate algometric measurements into assessments and diagnoses. Majority of studies completed algometry measurements by testing a pathologic or predetermined specific site multiple times within a set time period in between trials. This method is classified as the cluster protocol[35,37,39,42,43,45]. A different protocol identified by Bisset, Evans, and Tuttle is the circuit protocol which one site is tested and then moved on to the next site until all sites have been measured. Afterwards, the test sites were revisited in the same order until the number of measurements desired at each location has been obtained – thus a circuit[35].

Among the different ways to test pain pressure threshold, there have been a multitude of different test sites used to measure pain pressure threshold with an algometer. Some more commonly tested sites are the dorsal aspect of the wrist at the midline of the joint, the muscle belly of the tibialis anterior, the trapezius muscle between the spinous process on the seventh cervical vertebrae and lateral acromion, and the erector spinae – about 2 cm lateral of the fourth and fifth lumbar vertebrae junction[35,38,45]. The reason for the chosen anatomical sites could be that the sites are already sensitive areas that consist of bony and soft tissue areas. Additionally, Charleston et al. chose contralateral anatomical sites that corresponding to

pathological tender spots or 'hot spots'[36]. Fryer, Morris, and Gibbons research demonstrated that one can use the algometer to measure pain pressure threshold in deep muscles, specifically deep, medial paraspinal regions. The ability to reach and measure pain pressure threshold in deep muscles increases the potential application of algometers in clinical settings[45].

There are also different algometry tools to measure pain pressure threshold. Koo, Guo, and Brown found that using a manual, hand-held algometer device rather than a computerized algometer led to higher rates of test-retest reliability, repeatability, and sensitivity[37]. Several studies also found similar results of high inter-rater and intra-rater reliability using manual algometers[35,38,42,43]. Due to high levels of inter-rater and intra-rater reliability being identified by multiple investigators, it is evident that algometry can be employed in the clinical setting by both novice and experienced clinicians. Additionally, the multiple high reliability ratings also demonstrate the ability to use an algometer to measure pressure threshold measurements consistently and so the application of findings is possible.

Some studies indicate the reliability and feasibility of the use of algometry and pain pressure threshold and use as a diagnostic tool. Kregel et al. and Wilgen et al. used a handheld algometry device to diagnose patellar tendinopathy to aid with the diagnosis of patellar tendinopathy along with manual pressure and the Victorian Institute of Sports Assessment – Patellar (VISA-P) questionnaire within collegiate student athletes[39,43]. The use of algometers was also considered to evaluate the progression and impact of rehabilitation of patellar tendinopathy[39]. Kregel et al. specifically stated

that the use of an algometer had "…excellent sensitivity and specificity, and equivalent positive predictive value"[43] (Kregel et al, 2013, p 1773). Frank, McLaughlin, and Vaughan found that pain pressure threshold measurements on spinal segments were statistically stable with consecutive days of testing and same day testing[42]. Results from Frank et al. study demonstrate that algometer devices can be used as a repeatable measure for pain pressure threshold in patients with pain syndromes or diagnoses like low back pain as well as used to measure changes in pain experienced repeatedly[42]. The use of algometry is an appropriate method to quantify patients' pain levels in clinical settings and can be used repeatedly to provide quantified data regarding patients' pain levels over an extended period of time.

From the studies previously published, there is significant consensus that more future studies need to occur with larger sample sizes and investigate pain pressure threshold in different specialized populations. Additionally, larger sample sizes are needed for data analysis to include separate measurements via gender to determine if there is a gender influence on pain pressure threshold measured by algometer[38]. Studies that examined general population found that men tolerated more force applied in a various of sites compared to women[38,41]. Kregel et al, also found that healthy male and female athletes tolerated the similar amounts of force applied during algometry measurements (male athletes PPT 50.3±5.1, female athletes PPT 49.9±5.0)[43]. There is significant potential to use such a tool for the diagnosis of some pathologies as well as long term assessment of pain and influence the treatment being used.

Summary

Pain is the most common complaint that clinicians hear and is often the reason why people seek medical treatment. There have been studies that investigated the reliability and validity of different pain scales for general population. The literature also reveals that there are differences between general population and active populations regarding pain tolerance and pain threshold levels. However, it has yet to be researched if the commonly used pain scales used in the general population are as reliable and valid with active populations. Valid and reliable assessments of pain are required for effective pain management. The use of algometers could give a reliable measurement of pain that is quantified. Additionally, algometers can be used repeatedly to observe the progression of pathology or impact of treatment regarding pain measurement. To begin integrating algometry into common practices, more research needs to be completed to further demonstrate its efficacy and feasibility. The purpose of this study was to determine if there were correlations between the subjective measurements of commonly used pain scales to objectively measures with the use of an algometer.

III Methodology

One group specifically recruited was men and women student collegiate athletes that participate in National Collegiate Athletic Association (NCAA) sanctioned sports. Other potential participants were recruited through club activity participation as well as others whom self-identified as recreational athletes. These participants were collectively termed “non-collegiate athletes”. All participants did not have any restrictions from physical activity from their physicians but had some form of joint pain currently being experienced and were between the ages of 18-35. All participants were told that the study is voluntary and there were no repercussions for choosing to not participate in the study. Student collegiate athlete participants were specifically told that their answers would not have any impact on playing time or status on the team. Potential participants were asked if they would like to participate. If they agreed, then they filled out an informed consent form. Afterwards, participants completed a general information demographic form which includes age, years participating in the present sport/activity, gender, history of injury, sport, existence of current pain, pain rating, and injury status.

Participants then completed the following forms in a randomized order: numerical rating scale (NRS), 5-point verbal rating scale (VRS-5), visual analog scale (VAS), Mankoski scale, patient-specific functional scale (PSFS), pain catastrophizing scale (PCS), and the brief resilience scale (BRS) [see appendix]. The PCS and BRS were selected in order to determine if other psychological factors were connected to other parts of the data that would influence interpretation. The purpose of including the

PSFS was to determine if the participants had self-reported physical dysfunction with specific activities as well as pain. The randomization occurred by each pain scale being numbered one through four (NRS, VDS, VAS-5, Mankoski) and the other survey components (PSFS, PCS, BRS) were numbered one through three. An online random number generator was used to pick corresponding numbers. Each pain scale was alternated with one of the other surveys so there were not two pain scales in a row for the participant to complete.

Once the participant completed all forms, the examiner began the algometric measurements for the second portion of the experiment. The algometer data was collected using a circuit protocol, as explained by Bisset et al [35]. Subjects were seated on an examination table. The examiner placed the rubber end of the algometer (Wagner FPX FDX 25 force gauge) over the body region that was tested. The examiner pressed the algometer against the body area and instructed the subject to report when the pressure of the algometer device began to feel uncomfortable but not yet painful – thus measuring the pressure discomfort threshold (PDT). Without stopping, the examiner continued to apply pressure until the subject stated the pressure was painful and so measured the participant's pain pressure threshold (PPT) level. Measurements were taken on both sides of the body at the site the participant had reported joint pain as well as three predetermined anatomical locations. The predetermined sites were the erector spinae – 2 cm lateral to the fourth and fifth vertebrae junction, the "anatomical snuffbox" on the medial aspect of the joint line of the wrist, and the joint space inferior to the medial femoral epicondyle. Three

different measurements were taken at each site, rotating to the next site after each measurement was taken. If the participant presented with joint pain at a predetermined test site, then that site would account for the predetermined site as well as the site of joint pain for measurements rather than test the same site twice. In such cases then there would be 3 bilateral sites measured rather than 4. The clinician tested the site once and then rotated to the next site and continued until 3 measurements at all 4 sites were collected. The peak number measured each time, averaged and then the averaged value was used for statistical analysis.

Data Analysis

Summary statistics for demographic items were calculated and reported as means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Univariate comparisons were made between each group (sport level: collegiate athlete versus non-collegiate athlete), gender (men versus women), and current injury (yes versus no) using independent t-tests based on normality of each variable distribution. The distribution of data was normal from the Shapiro-Wilk test. Pearson's correlations (r) were performed to determine if a relationship existed amongst any of the dependent variables. The correlations were performed for all subjects as well as for each group. Correlation coefficients were interpreted as: 0.00-0.30=negligible; 0.31-0.50=low positive correlation; 0.51-0.70=moderate positive correlation; 0.71-0.90=high positive correlation; and 0.91-1.00-very high positive correlation[51]. Any negative correlations would be interpreted as the inverse of the positive correlation interpretation.

Statistical significance was set at $p \leq 0.05$. All analyses were performed on SPSS (v26, IBM, Armonk, NY).

To ensure the consistency of measurement obtained by the examiner, a reliability assessment for each of the algometer sites was performed. A sample of seven participants who were not included in the actual study was obtained for this purpose. Using a two-way random design (2,1), intraclass correlation coefficients (ICC) were calculated from the two trials of each test site obtained for a single examiner. This same examiner also gathered all of the study data for all trials. Intrasession test/retest reliability was calculated. Once the ICC's were determined, standard error of measurement (SEM) and minimal detectable change (MDC) at the 90% confidence level were calculated. An ICC ≥0.75 was interpreted as excellent while values between 0.40–0.74 were considered fair to good and <0.40 was considered poor[52]. Test/re-test intrasession reliability was revealed to be excellent (ICC≥0.78) for all testing sites (Table 1).

A sample size of 62 participants would have 80% power for a low positive correlation of r=0.35 between the pain assessments with a two-sided significance level of 0.05. To account for 10% attrition, collection continued until 69 participants completed the study.

Results

The total sample size included 69 participants (Age: 21.3 ± 2.2, 33 men, 36 women). The participants averaged 11.5 ± 7.0 hours per week in physical activity. Within the men, 18 were NCAA collegiate athletes while 15 were club, recreational, or

non-collegiate athletes. Within the women, 14 were NCAA collegiate athletes while 22 were club, recreational, or non-athletes.

Table 1: Reliability Table

	Mean (±SD)	ICC	SEM	MDC	Lower CI	Upper CI
R wrist PDT	23.1±8.8	0.93	2.3	5.4	0.6	0.99
R wrist PPT	29.6±9.5	0.93	2.5	5.8	0.57	0.99
R wrist PR	2.0±1.1	0.96	0.2	0.5	0.77	0.99
L wrist PDT	24.7±9.2	0.94	2.2	5.2	0.67	0.99
L wrist PPT	32.1±10.2	0.92	2.9	6.7	0.51	0.99
L wrist PR	2.0±1.1	0.99	0.1	0.2	0.98	0.99
R knee PDT	42.9±16.7	0.83	6.9	16.1	0.01	0.97
R knee PPT	57.4±20.5	0.78	9.6	22.4	-0.26	0.96
R knee PR	1.7±1.1	0.96	0.2	0.5	0.78	0.99
L knee PDT	42.8±20.1	0.94	4.9	11.5	0.65	0.99
L knee PPT	56.4±22.3	0.9	7.1	16.5	0.4	0.98
L knee PR	1.6±1.1	0.98	0.2	0.4	0.88	0.99
R back PDT	37.6±16.0	0.95	3.6	8.3	0.72	0.99
R back PPT	49.4±16.6	0.8	7.4	17.3	-0.16	0.97
R back PR	1.6±1.1	0.98	0.2	0.4	0.87	0.99
L back PDT	43.1±25.7	0.94	6.3	14.7	0.66	0.99

Table 1 (Continued)

	Mean (±SD)	ICC	SEM	MDC	Lower CI	Upper CI
L back PPT	55.8±27.6	0.96	5.5	12.9	0.75	0.99
L back PR	1.8±1.3	0.98	0.2	0.4	0.91	0.99

Amongst sport level (collegiate athlete versus non-collegiate athlete), there were two significant differences (Table 2). First, there were significantly higher ratings on the NRS for collegiate athletes (collegiate athlete NRS = 4.0 ± 1.9) compared to non-collegiate athletes (non-collegiate athlete NRS = 2.9 ± 1.7, $p = 0.016$). Second, the PSFS ratings for collegiate athletes (PSFS = 12.35 ± 6.9, $p = 0.035$) were significantly lower compared to the non-collegiate athletes (PSFS = 15.5 ± 5.2). There were similar scores seen between collegiate athlete and non-collegiate athlete groups regarding BRS and PCS. While not statistically significant, the collegiate athletes consistently tolerated more force applied during the algometry measurements than the non-collegiate athletes, which is consistent with current literature.

Within the collegiate athletes' data, the Mankoski scale was the only pain scale that had consistently moderate to high positive correlations to the other pain scales ($r = 0.511$-0.730, $p \leq 0.003$). The VRS-5 was the only pain scale significantly correlated to the injured PDT and PPT but it was a low negative correlation ($r = -0.374$-0.388, $p \leq 0.042$). The only correlation between pain scales and PCS was VRS-5 had a low positive correlation to PCS total score ($r = 0.413$, $p = 0.026$). Within the non-collegiate athletes' group, there was a more consistent moderate to high positive correlations between all of the pain scales ($r = 0.518$-0.820, $p \leq 0.002$). The PCS total as well as rumination and

helplessness subcategories had consistently low to moderate positive correlations to all of the pain scales ($r = 0.425\text{-}0.570$, $p \leq 0.009$). The PCS helplessness was found to have a low negative correlation to PSFS ($r = -0.346$, $p = 0.039$). The only variable correlated to the algometry measurements was BRS which had a low positive to both injured and non-injured PDT/ PPT values ($r = 0.338\text{-}0.463$, $p \leq 0.041$).

Table 2: Summary Statistics for Collegiate Athlete versus Non-Collegiate Athlete

		Mean	P-value
NRS	Athlete (n=32)	4.0 ± 1.9	**0.016**
	Non-Athlete (n=37)	2.9 ± 1.7	
VAS	Athlete (n=28)	3.7 ± 2.1	0.168
	Non-Athlete (n=37)	3.0 ± 1.9	
VRS-5	Athlete (n=30)	1.8 ± 0.8	0.878
	Non-Athlete (n=36)	1.8 ± 0.7	
Mankoski	Athlete (n=31)	3.1 ± 1.9	0.889
	Non-Athlete (n=35)	3.1 ± 1.5	
PCS Total	Athlete (n=32)	15.7 ± 9.7	0.484
	Non-Athlete (n=37)	14.0 ± 10.0	
PCS Rumination	Athlete (n=31)	5.0 ± 3.3	0.851
	Non-Athlete (n=37)	5.3 ± 4.4	
PCS Magnification	Athlete (n=31)	4.0 ± 2.3	0.118
	Non-Athlete (n=37)	3.1 ± 2.6	
PCS Helplessness	Athlete (n=31)	6.4 ± 5.4	0.569
	Non-Athlete (n=37)	5.7 ± 4.4	
PSFS Total	Athlete (n=31)	12.35 ± 6.9	**0.035**
	Non-Athlete (n=36)	15.5 ± 5.2	
BRS Total	Athlete (n=32)	22.5 ± 4.3	0.813
	Non-Athlete (n=37)	22.3 ± 4.8	
Avg PDT injured side	Athlete (n =32)	50.5 ± 30.7	0.397
	Non-Athlete (n=37)	43.8 ± 34.4	
Avg PPT injured side	Athlete (n=32)	63.5 ± 34.7	0.412
	Non-Athlete (n=37)	56.0 ± 39.7	
Avg PDT non-injured	Athlete (n=32)	55.3 ± 29.6	0.159
	Non-Athlete (n=36)	44.6 ± 31.8	
Avg PPT non-injured	Athlete (n=32)	66.8 ± 32.6	0.427
	Non-Athlete (n=36)	60.0 ± 37.4	

Table 3: Correlation Statistics for Collegiate Athlete versus Non-Collegiate Athlete

Athlete	NRS	VAS	VRS 5	Mankoski	PCS total	PCS rum	PCS mag	PCS help	PSFS total	BRS total	avg inj PDT	avg inj PPT	avg n-inj PDT	avg n-inj PPT
NRS	1	.612**	0.234	.511**	0.281	0.296	0.143	0.260	0.103	-0.103	-0.245	-0.207	-0.261	-0.184
P-value		**0.001**	0.214	**0.003**	0.119	0.106	0.443	0.158	0.581	0.575	0.177	0.256	0.150	0.314
VAS	.612**	1	.519**	.730**	0.164	0.218	-0.032	0.156	0.001	-0.181	-0.236	-0.227	-0.243	-0.179
P-value	**0.001**		**0.007**	**0.000**	0.404	0.274	0.876	0.436	0.996	0.357	0.226	0.245	0.212	0.362
VRS 5	0.234	.519**	1	.565**	0.323	0.190	0.050	.413*	0.157	-0.068	-.374*	-0.353	-.388*	-0.354
P-value	0.214	**0.007**		**0.001**	0.082	0.323	0.798	**0.026**	0.416	0.723	**0.042**	0.055	**0.034**	0.055
Mankoski	.511**	.730**	.565**	1	0.277	0.198	0.040	0.338	0.154	-0.010	-0.156	-0.135	-0.244	-0.145
P-value	**0.003**	**0.000**	**0.001**		0.131	0.294	0.836	0.068	0.418	0.959	0.401	0.469	0.185	0.437
PCS total	0.281	0.164	0.323	0.277	1	.911**	.821**	.926**	0.096	-0.272	0.000	0.045	-0.069	-0.107
P-value	0.119	0.404	0.082	0.131		**0.000**	**0.000**	**0.000**	0.607	0.133	0.999	0.807	0.709	0.559
PCS rum	0.296	0.218	0.190	0.198	.911**	1	.795**	.723**	0.064	-.416*	-0.004	0.041	-0.068	-0.107
P-value	0.106	0.274	0.323	0.294	**0.000**		**0.000**	**0.000**	0.739	**0.020**	0.985	0.828	0.716	0.565
PCS mag	0.143	-0.032	0.050	0.040	.821**	.795**	1	.596**	-0.005	-0.346	-0.004	0.057	-0.042	-0.091
P-value	0.443	0.876	0.798	0.836	**0.000**	**0.000**		**0.000**	0.977	0.056	0.982	0.762	0.822	0.627
PCS help	0.260	0.156	.413*	0.338	.926**	.723**	.596**	1	0.169	-0.090	0.026	0.056	-0.041	-0.068
P-value	0.158	0.436	**0.026**	0.068	**0.000**	**0.000**	**0.000**		0.373	0.630	0.891	0.763	0.828	0.716
PSFS total	0.103	0.001	0.157	0.154	0.096	0.064	-0.005	0.169	1	0.019	-0.191	-0.156	-0.201	-0.124
P-value	0.581	0.996	0.416	0.418	0.607	0.739	0.977	0.373		0.917	0.303	0.402	0.277	0.506
BRS total	-0.103	-0.181	-0.068	-0.010	-0.272	-.416*	-0.346	-0.090	0.019	1	0.069	0.084	-0.015	0.097
P-value	0.575	0.357	0.723	0.959	0.133	**0.020**	0.056	0.630	0.917		0.707	0.647	0.935	0.597
avg inj PDT	-0.245	-0.236	-.374*	-0.156	0.000	-0.004	-0.004	0.026	-0.191	0.069	1	.983**	.922**	.936**
P-value	0.177	0.226	**0.042**	0.401	0.999	0.985	0.982	0.891	0.303	0.707		**0.000**	**0.000**	**0.000**
avg inj PPT	-0.207	-0.227	-0.353	-0.135	0.045	0.041	0.057	0.056	-0.156	0.084	.983**	1	.907**	.949**
P-value	0.256	0.245	0.055	0.469	0.807	0.828	0.762	0.763	0.402	0.647	**0.000**		**0.000**	**0.000**
avg n-inj PDT	-0.261	-0.243	-.388*	-0.244	-0.069	-0.068	-0.042	-0.041	-0.201	-0.015	.922**	.907**	1	.942**
P-value	0.150	0.212	**0.034**	0.185	0.709	0.716	0.822	0.828	0.277	0.935	**0.000**	**0.000**		**0.000**
avg n-inj PPT	-0.184	-0.179	-0.354	-0.145	-0.107	-0.107	-0.091	-0.068	-0.124	0.097	.936**	.949**	.942**	1
P-value	0.314	0.362	0.055	0.437	0.559	0.565	0.627	0.716	0.506	0.597	**0.000**	**0.000**	**0.000**	

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Table 3 (Continued)

Non-collegiate	NRS	VAS	VRS 5	Mankoski	PCS total	PCS rum	PCS mag	PCS help	PSFS total	BRS total	avg inj PDT	avg inj PPT	avg n-inj PDT	avg n-inj PPT
NRS	1	.820**	.693**	.562**	.553**	.554**	0.259	.556**	-0.212	-0.202	-0.150	-0.149	-0.173	-0.124
P-value		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.122	**0.000**	0.215	0.230	0.376	0.380	0.312	0.470
VAS	.820**	1	.596**	.545**	.482**	.454**	0.170	.538**	-0.210	-0.192	0.056	0.037	-0.014	0.034
P-value	**0.000**		**0.000**	**0.001**	**0.003**	**0.005**	0.314	**0.001**	0.218	0.256	0.743	0.826	0.933	0.846
VRS 5	.693**	.596**	1	.518**	.532**	.570**	0.146	.548**	-0.299	0.040	-0.042	-0.062	-0.039	-0.042
P-value	**0.000**	**0.000**		**0.002**	**0.001**	**0.000**	**0.397**	**0.001**	0.081	0.815	0.807	0.718	0.824	0.813
Mankoski	.562**	.545**	.518**	1	.443**	.436**	0.252	.425*	-0.253	0.036	-0.097	-0.141	-0.158	-0.141
P-value	**0.000**	**0.001**	**0.002**		**0.008**	**0.009**	0.144	**0.011**	0.150	0.836	0.580	0.419	0.373	0.427
PCS total	.553**	.482**	.532**	.443**	1	.927**	.727**	.943**	-0.253	-0.177	-0.105	-0.151	-0.140	-0.140
P-value	**0.000**	**0.003**	**0.001**	**0.008**		**0.000**	**0.000**	**0.000**	0.137	0.293	0.536	0.373	0.416	0.414
PCS rum	.554**	.454**	.570**	.436**	.927**	1	.518**	.820**	-0.168	-0.224	0.033	-0.262	-0.269	-0.253
P-value	**0.000**	**0.005**	**0.000**	**0.009**	**0.000**		**0.001**	**0.000**	0.329	0.182	0.164	0.117	0.112	0.136
PCS mag	0.259	0.170	0.146	0.252	**.727****	**.518****	1	.587**	-0.112	-0.075	0.135	0.086	0.113	0.087
P-value	0.122	0.314	0.397	0.144	**0.000**	**0.001**		**0.000**	0.514	0.659	0.426	0.613	0.512	0.615
PCS help	.556**	.538**	.548**	.425*	.943**	.820**	.587**	1	-.346*	-0.117	-0.063	-0.111	-0.092	-0.096
P-value	**0.000**	**0.001**	**0.001**	**0.011**	**0.000**	**0.000**	**0.000**		**0.039**	0.491	0.712	0.514	0.595	0.578
PSFS total	-0.212	-0.210	-0.299	-0.253	-0.253	-0.168	-0.112	-.346*	1	0.204	0.063	0.095	0.049	0.043
P-value	0.215	0.218	0.081	0.150	0.137	0.329	0.514	**0.039**		0.232	0.713	0.583	0.781	0.806
BRS total	-0.202	-0.192	0.040	0.036	-0.177	-0.224	-0.075	-0.117	0.204	1	.351*	.338*	.463**	.408*
P-value	0.230	0.256	0.815	0.836	0.293	0.182	0.659	0.491	0.232		**0.033**	**0.041**	**0.004**	**0.014**
avg inj PDT	-0.150	0.056	-0.042	-0.097	-0.105	-0.234	0.135	-0.063	0.063	.351*	1	.984**	.949**	.928**
P-value	0.376	0.743	0.807	0.580	0.536	0.164	0.426	0.712	0.713	**0.033**		**0.000**	**0.000**	**0.000**
avg inj PPT	-0.149	0.037	-0.062	-0.141	-0.151	-0.262	0.086	-0.111	0.095	.338*	.984**	1	.952**	.961**
P-value	0.380	0.826	0.718	0.419	0.373	0.117	0.613	0.514	0.583	**0.041**	**0.000**		**0.000**	**0.000**
avg n-inj PDT	-0.173	-0.014	-0.039	-0.158	-0.140	-0.269	0.113	-0.092	0.049	.463**	.949**	.952**	1	.972**
P-value	0.312	0.933	0.824	0.373	0.416	0.112	0.512	0.595	0.781	**0.004**	**0.000**	**0.000**		**0.000**
avg n-inj PPT	-0.124	0.034	-0.042	-0.141	-0.140	-0.253	0.087	-0.096	0.043	.408*	.928**	.961**	.972**	1
P-value	0.470	0.846	0.813	0.427	0.414	0.136	0.615	0.578	0.806	**0.014**	**0.000**	**0.000**	**0.000**	

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

There were no significant differences found when the data was sorted by gender (Table 4). Both men and women had similar pain rating ranges (men: 1.7-3.8, women: 1.9-3.3) but men tolerated higher amounts of force (men: 50.2-68.8N, women: 43.9-57.9N), congruent with current literature. While men and women had similar PCS values with no statistical significance, men consistently had slightly elevated levels with exception to PCS helplessness. Within the men's data, all of the pain scales had low to high positive correlations to each other ($r = 0.492\text{-}0.784$, $p \leq 0.005$). The PCS total had low positive correlations to all the pain scales, except Mankoski ($r = 0.352\text{-}0.411$, $p \leq 0.048$). The VRS-5 was the only pain scale with low negative correlations to the algometry measurements ($r = -0.374\text{-}0.383$, $p \leq 0.038$).

Within the women's data, all of the pain scales had low to moderate positive correlations ($r = 0.437\text{-}0.69$, $p \leq 0.01$). The PCS total and helplessness scores had consistent low positive correlations to all of the pain scales ($r = 0.351\text{-}0.464$, $p \leq 0.045$). BRS had low positive correlation to the average PDT and PPT on the injured side ($r = 0.343\text{-}0.405$, $p \leq 0.043$) (Table 5).

Table 4: Summary Statistics by Gender

		Mean	P-value
NRS	Female (n=36)	3.1 ± 1.9	0.118
	Male (n=33)	3.8 ± 1.8	
VAS	Female (n=33)	3.25 ± 2.0	0.943
	Male (n=32)	3.3 ± 2.0	
VRS-5	Female (n=35)	1.9 ± 0.7	0.253
	Male (n=31)	1.7 ± 0.8	
Mankoski	Female (n=35)	3.2 ± 1.5	0.566
	Male (n=31)	3.0 ± 2.0	
PCS Total	Female (n=36)	14.5 ± 9.2	0.844
	Male (n=33)	15.0 ± 10.7	
PCS Rumination	Female (n=35)	5.0 ± 4.0	0.679
	Male (n=33)	5.4 ± 3.85	
PCS Magnification	Female (n=35)	3.3 ± 2.4	0.440
	Male (n=33)	3.8 ± 2.6	
PCS Helplessness	Female (n=35)	6.1 ± 4.1	0.903
	Male (n=33)	6.0 ± 5.7	
PSFS Total	Female (n=35)	13.8 ± 14.3	0.722
	Male (n=32)	14.3 ± 5.9	
BRS Total	Female (n=36)	22.7 ± 4.4	0.565
	Male (n=33)	22.0 ± 4.7	
Avg PDT injured side	Female (n=36)	43.9 ± 34.0	0.429
	Male (n=33)	50.2 ± 31.2	
Avg PPT injured side	Female (n=36)	55.05 ± 38.6	0.304
	Male (n=33)	64.4 ± 35.9	
Avg PDT non-injured	Female (n=35)	45.9 ± 30.7	0.315
	Male (n=33)	53.5 ± 31.3	
Avg PPT non-injured	Female (n=35)	57.9 ± 35.85	0.201
	Male (n=33)	68.8 ± 34.0	

Table 5: Correlation Statistics for Gender

Female	NRS	VAS	VRS 5	Mankoski	PCS total	PCS rum	PCS mag	PCS help	PSFS total	BRS total	avg inj PDT	avg inj PPT	avg n-inj PDT	avg n-inj PPT
NRS	1	.690**	.464**	.439**	.460**	.417*	0.304	.443**	-0.174	-0.220	-0.111	-0.097	-0.105	-0.076
P-value		**0.000**	**0.005**	**0.008**	**0.005**	**0.013**	0.075	**0.008**	0.316	0.197	0.521	0.574	0.547	0.662
VAS	.690**	1	.525**	.569**	.351*	0.327	0.086	.400*	-0.187	-0.150	0.034	0.032	-0.006	0.060
P-value	**0.000**		**0.002**	**0.001**	**0.045**	0.068	0.641	**0.023**	0.297	0.404	0.849	0.860	0.975	0.744
VRS 5	.464**	.525**	1	.437**	.464**	.528**	0.139	.420*	-0.211	-0.020	-0.010	0.012	0.014	0.041
P-value	**0.005**	**0.002**		**0.010**	**0.005**	**0.001**	0.433	**0.013**	0.231	0.908	0.955	0.946	0.937	0.816
Mankoski	.439**	.569**	.437**	1	.449**	.413*	0.240	.457**	-0.080	0.161	-0.051	-0.070	-0.134	-0.056
P-value	**0.008**	**0.001**	**0.010**		**0.007**	**0.015**	0.171	**0.007**	0.651	0.357	0.772	0.689	0.450	0.752
PCS total	.460**	.351*	.464**	.449**	1	.919**	.779**	.937**	-0.174	-0.285	-0.055	-0.062	-0.106	-0.110
P-value	**0.005**	**0.045**	**0.005**	**0.007**		**0.000**	**0.000**	**0.000**	0.318	0.093	0.748	0.717	0.545	0.529
PCS rum	.417*	0.327	.528**	.413*	.919**	1	.576**	.793**	-0.060	-0.296	-0.140	-0.134	-0.182	-0.158
P-value	**0.013**	0.068	**0.001**	**0.015**	**0.000**		**0.000**	**0.000**	0.737	0.084	0.422	0.444	0.303	0.373
PCS mag	0.304	0.086	0.139	0.240	.779**	.576**	1	.636**	-0.169	-0.289	0.001	-0.026	-0.053	-0.117
P-value	0.075	0.641	0.433	0.171	**0.000**	**0.000**		**0.000**	0.340	0.092	0.996	0.882	0.765	0.511
PCS help	.443**	.400*	.420*	.457**	.937**	.793**	.636**	1	-0.197	-0.182	0.026	0.018	-0.014	-0.011
P-value	**0.008**	**0.023**	**0.013**	**0.007**	**0.000**	**0.000**	**0.000**		0.264	0.297	0.884	0.917	0.935	0.952
PSFS total	-0.174	-0.187	-0.211	-0.080	-0.174	-0.060	-0.169	-0.197	1	0.117	0.043	0.031	-0.003	0.016
P-value	0.316	0.297	0.231	0.651	0.318	0.737	0.340	0.264		0.502	0.807	0.859	0.988	0.930
BRS total	-0.220	-0.150	-0.020	0.161	-0.285	-0.296	-0.289	-0.182	0.117	1	0.285	0.300	.343*	.405*
P-value	0.197	0.404	0.908	0.357	0.093	0.084	0.092	0.297	0.502		0.092	0.075	**0.043**	**0.016**
avg inj PDT	-0.111	0.034	-0.010	-0.051	-0.055	-0.140	0.001	0.026	0.043	0.285	1	.990**	.915**	.927**
P-value	0.521	0.849	0.955	0.772	0.748	0.422	0.996	0.884	0.807	0.092		**0.000**	**0.000**	**0.000**
avg inj PPT	-0.097	0.032	0.012	-0.070	-0.062	-0.134	-0.026	0.018	0.031	0.300	.990**	1	.915**	.945**
P-value	0.574	0.860	0.946	0.689	0.717	0.444	0.882	0.917	0.859	0.075	**0.000**		**0.000**	**0.000**
avg n-inj PDT	-0.105	-0.006	0.014	-0.134	-0.106	-0.182	-0.053	-0.014	-0.003	.343*	.915**	.915**	1	.950**
P-value	0.547	0.975	0.937	0.450	0.545	0.303	0.765	0.935	0.988	**0.043**	**0.000**	**0.000**		**0.000**
avg n-inj PPT	-0.076	0.060	0.041	-0.056	-0.110	-0.158	-0.117	-0.011	0.016	.405*	.927**	.945**	.950**	1
P-value	0.662	0.744	0.816	0.752	0.529	0.373	0.511	0.952	0.930	**0.016**	**0.000**	**0.000**	**0.000**	

Continued on next page

Table 5 (Continued)

Male	NRS	VAS	VRS 5	Mankoski	PCS total	PCS rum	PCS mag	PCS help	PSFS total	BRS total	avg inj PDT	avg inj PPT	avg n-inj PDT	avg n-inj PPT
NRS	1	.784**	.492**	.623**	.404*	.407*	0.163	.402*	-0.031	-0.031	-0.258	-0.249	-0.264	-0.236
P-value		**0.000**	**0.005**	**0.000**	**0.020**	**0.019**	0.365	**0.020**	0.865	0.864	0.147	0.162	0.137	0.187
VAS	.784**	1	.583**	.724**	.352*	.383*	0.138	0.328	-0.084	-0.215	-0.152	-0.159	-0.171	-0.145
P-value	**0.000**		**0.001**	**0.000**	**0.048**	**0.030**	0.451	0.066	0.654	0.237	0.408	0.386	0.350	0.428
VRS 5	.492**	.583**	1	.615**	.411*	0.318	0.090	.512**	0.165	-0.016	-.374*	-.383*	-.377*	-.375*
P-value	**0.005**	**0.001**		**0.000**	**0.022**	0.081	0.631	**0.003**	0.385	0.931	**0.038**	**0.033**	**0.037**	**0.037**
Mankoski	.623**	.724**	.615**	1	0.295	0.269	0.092	0.330	0.058	-0.104	-0.175	-0.177	-0.230	-0.192
P-value	**0.000**	**0.000**	**0.000**		0.107	0.144	0.622	0.070	0.762	0.579	0.345	0.341	0.213	0.300
PCS total	.404*	.352*	.411*	0.295	1	.905**	.751**	.934**	0.007	-0.151	-0.052	-0.063	-0.087	-0.133
P-value	**0.020**	**0.048**	**0.022**	0.107		**0.000**	**0.000**	**0.000**	0.968	0.401	0.774	0.726	0.630	0.459
PCS rum	.407*	.383*	0.318	0.269	.905**	1	.618**	.746**	-0.035	-0.286	-0.178	-0.198	-0.223	-0.270
P-value	**0.019**	**0.030**	0.081	0.144	**0.000**		**0.000**	**0.000**	0.849	0.107	0.321	0.269	0.212	0.128
PCS mag	0.163	0.138	0.090	0.092	.751**	.618**	1	.561**	-0.039	-0.057	0.188	0.197	0.188	0.164
P-value	0.365	0.451	0.631	0.622	**0.000**	**0.000**		**0.001**	0.830	0.755	0.294	0.272	0.296	0.363
PCS help	.402*	0.328	.512**	0.330	.934**	.746**	.561**	1	0.058	-0.046	-0.042	-0.055	-0.078	-0.122
P-value	**0.020**	0.066	**0.003**	0.070	**0.000**	**0.000**	**0.001**		0.754	0.798	0.818	0.759	0.666	0.499
PSFS total	-0.031	-0.084	0.165	0.058	0.007	-0.035	-0.039	0.058	1	0.076	-0.278	-0.186	-0.276	-0.190
P-value	0.865	0.654	0.385	0.762	0.968	0.849	0.830	0.754		0.678	0.124	0.308	0.126	0.299
BRS total	-0.031	-0.215	-0.016	-0.104	-0.151	-0.286	-0.057	-0.046	0.076	1	0.204	0.192	0.203	0.184
P-value	0.864	0.237	0.931	0.579	0.401	0.107	0.755	0.798	0.678		0.255	0.285	0.258	0.305
avg inj PDT	-0.258	-0.152	-.374*	-0.175	-0.052	-0.178	0.188	-0.042	-0.278	0.204	1	.975**	.963**	.940**
P-value	0.147	0.408	**0.038**	0.345	0.774	0.321	0.294	0.818	0.124	0.255		**0.000**	**0.000**	**0.000**
avg inj PPT	-0.249	-0.159	-.383*	-0.177	-0.063	-0.198	0.197	-0.055	-0.186	0.192	.975**	1	.950**	.970**
P-value	0.162	0.386	**0.033**	0.341	0.726	0.269	0.272	0.759	0.308	**0.000**			**0.000**	**0.000**
avg n-inj PDT	-0.264	-0.171	-.377*	-0.230	-0.087	-0.223	0.188	-0.078	-0.276	0.203	.963**	.950**	1	.965**
P-value	0.137	0.350	**0.037**	0.213	0.630	0.212	0.296	0.666	0.126	0.258	**0.000**	**0.000**		**0.000**
avg n-inj PPT	-0.236	-0.145	-.375*	-0.192	-0.133	-0.270	0.164	-0.122	-0.190	0.184	.940**	.970**	.965**	1
P-value	0.187	0.428	**0.037**	0.300	0.459	0.128	0.363	0.499	0.299	0.305	**0.000**	**0.000**	**0.000**	

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

The data was also sorted and analyzed by current injury status. Participants who identified as injured had a higher NRS pain rating score (4.2 ± 1.8) compared to participants who were not injured (2.9 ± 1.8, $p = 0.005$). Additionally, the same results were found regarding the VAS (injured = 4.1 ± 2.1, $p = 0.006$, non-injured = 2.7 ±1.76) and the Mankoski scale (injured = 4.12 ± 2.1, $p = 0.045$, non-injured = 2.7 ± 1.76). Those who were injured also reported lower values on the PSFS compared to non-injured (injured: 12.5±6.1, non-injured: 15.05±6.1). The injured group also consistently tolerated a similar amount of force as the non-injured group on both the injured and non-injured sides (injured group on injured side PDT: 46.8±33N, uninjured group on injured side PDT: 47.0±32.8N, injured group on injured side PPT: 59.6±37.5N, uninjured group on injured side PPT: 59.4±37.7N, injured group on uninjured side PDT: 52.7±32.2N, uninjured group on uninjured side PDT: 47.8±30.5N, injured group on uninjured side PPT: 66.7±35.6N, uninjured group on uninjured side PPT: 61.1±35.1N) (Table 6).

Within the injured group's data, the pain scales had low to high positive correlations to each other ($r = 0.454$-0.833, $p \leq 0.023$). Only the VRS-5 scale had a connection to the PCS total and PCS helplessness scores with low to moderate positive correlations ($r = 0.461$-0.555, $p \leq 0.021$). Additionally, the VRS-5 was the only pain scale connected to algometry measurements with a low to moderate negative correlation ($r = -0.471$-0.514, $p \leq 0.023$). Within the non-injured group, all of the pain scales had low to moderate positive correlations to each other ($r = 0.369$-0.604, $p \leq 0.019$). The PCS total and rumination scores had low positive correlations to all of the

pain scales (r = 0.336-0.49, p ≤ 0.034). The PCS helplessness subcategory had low positive correlations to all pain scales, except Mankoski (r = 0.329-0.487, p ≤ 0.036). The BRS had low negative correlations to VAS and PCS rumination (r = -0.756-0.382, p ≤ 0.024). The BRS scores were also correlated to the average PDT and PPT values on both injured and uninjured sides with low positive correlations (r = 0.332-0.378, p ≤ 0.03)(Table 7).

Table 6: Summary Statistics by Current Injury

		Mean	P-value
NRS	No Injury (n=43)	2.9 ± 1.8	**0.005**
	Injury (n=26)	4.2 ± 1.8	
VAS	No Injury (n=40)	2.7 ± 1.8	**0.006**
	Injury (n=25)	4.1 ± 2.1	
VRS-5	No Injury (n=41)	1.7 ± 0.6	0.110
	Injury (n=25)	2.0 ± 0.9	
Mankoski	No Injury (n=40)	2.8 ± 1.5	**0.045**
	Injury (n=26)	3.6 ± 1.9	
PCS Total	No Injury (n=43)	13.9 ± 8.9	0.337
	Injury (n=26)	16.2 ± 11.3	
PCS Rumination	No Injury (n=43)	4.7 ± 3.5	0.175
	Injury (n=25)	6.0 ± 4.3	
PCS Magnification	No Injury (n=43)	3.65 ± 2.6	0.558
	Injury (n=25)	3.3 ± 2.4	
PCS Helplessness	No Injury (n=43)	5.6 ± 3.8	0.404
	Injury (n=25)	6.8 ± 6.3	
PSFS Total	No Injury (n=41)	15.05 ± 6.1	0.100
	Injury (n=26)	12.5 ± 6.1	
BRS Total	No Injury (n=43)	22.7 ± 4.8	0.441
	Injury (n=26)	21.85 ± 4.0	
Avg PDT injured side	No Injury (n=43)	47.0 ± 32.8	0.983
	Injury (n=26)	46.8 ± 33.0	
Avg PPT injured side	No Injury (n=43)	59.4 ± 37.7	0.981
	Injury (n=26)	59.6 ± 37.5	
Avg PDT non-injured	No Injury (n=43)	47.8 ± 30.5	0.531
	Injury (n=25)	52.7 ± 32.2	
Avg PPT non-injured	No Injury (n=43)	61.1 ± 35.1	0.529
	Injury (n=25)	66.7 ± 35.6	

Table 7: Correlation Statistics for Current Injury

Injured	NRS	VAS	VRS 5	Mankoski	PCS total	PCS rum	PCS mag	PCS help	PSFS total	BRS total	avg inj PDT	avg inj PPT	avg n-inj PDT	avg n-inj PPT
NRS	1	.833**	.454*	.596**	0.319	0.275	0.212	0.304	0.117	0.182	-0.159	-0.123	-0.207	-0.100
P-value		**0.000**	**0.023**	**0.001**	0.112	0.184	0.309	0.140	0.568	0.374	0.436	0.551	0.321	0.635
VAS	.833**	1	.557**	.726**	0.309	0.284	0.101	0.318	0.061	0.207	-0.133	-0.136	-0.209	-0.102
P-value	**0.000**		**0.005**	**0.000**	0.133	0.179	0.637	0.130	0.771	0.320	0.526	0.517	0.328	0.636
VRS 5	.454*	.557**	1	.555**	.461*	0.361	0.024	.555**	0.097	0.102	-.475*	-.471*	-.514*	-.463*
P-value	**0.023**	**0.005**		**0.004**	**0.021**	0.084	0.913	**0.005**	0.646	0.627	**0.016**	**0.017**	**0.010**	**0.023**
Mankoski	.596**	.726**	.555**	1	0.349	0.242	0.118	.407*	0.220	0.238	-0.284	-0.278	-0.357	-0.263
P-value	**0.001**	**0.000**	**0.004**		0.081	0.244	0.574	**0.043**	0.281	0.241	0.160	0.170	0.080	0.204
PCS total	0.319	0.309	.461*	0.349	1	.905**	.718**	.931**	0.050	-0.091	-0.107	-0.125	-0.147	-0.199
P-value	0.112	0.133	**0.021**	0.081		**0.000**	**0.000**	**0.000**	0.808	0.657	0.604	0.544	0.483	0.340
PCS rum	0.275	0.284	0.361	0.242	.905**	1	.614**	.733**	0.013	-0.128	-0.115	-0.136	-0.176	-0.195
P-value	0.184	0.179	0.084	0.244	**0.000**		**0.001**	**0.000**	0.952	0.542	0.585	0.517	0.410	0.360
PCS mag	0.212	0.101	0.024	0.118	.718**	.614**	1	.512**	-0.046	-0.286	-0.033	-0.054	-0.020	-0.127
P-value	0.309	0.637	0.913	0.574	**0.000**	**0.001**		**0.009**	0.826	0.166	0.875	0.798	0.928	0.555
PCS help	0.304	0.318	.555**	.407*	.931**	.733**	.512**	1	0.131	0.034	-0.089	-0.100	-0.123	-0.164
P-value	0.140	0.130	**0.005**	**0.043**	**0.000**	**0.000**	**0.009**		0.532	0.870	0.671	0.636	0.567	0.444
PSFS total	0.117	0.061	0.097	0.220	0.050	0.013	-0.046	0.131	1	0.118	-0.164	-0.086	-0.157	-0.049
P-value	0.568	0.771	0.646	0.281	0.808	0.952	0.826	0.532		0.567	0.423	0.676	0.454	0.816
BRS total	0.182	0.207	0.102	0.238	-0.091	-0.128	-0.286	0.034	0.118	1	0.032	0.048	0.065	0.140
P-value	0.374	0.320	0.627	0.241	0.657	0.542	0.166	0.870	0.567		0.877	0.816	0.756	0.505
avg inj PDT	-0.159	-0.133	-.475*	-0.284	-0.107	-0.115	-0.033	-0.089	-0.164	0.032	1	.980**	.963**	.936**
P-value	0.436	0.526	**0.016**	0.160	0.604	0.585	0.875	0.671	0.423	0.877		**0.000**	**0.000**	**0.000**
avg inj PPT	-0.123	-0.136	-.471*	-0.278	-0.125	-0.136	-0.054	-0.100	-0.086	0.048	.980**	1	.951**	.965**
P-value	0.551	0.517	**0.017**	0.170	0.544	0.517	0.798	0.636	0.676	0.816	**0.000**		**0.000**	**0.000**
avg n-inj PDT	-0.207	-0.209	-.514*	-0.357	-0.147	-0.176	-0.020	-0.123	-0.157	0.065	.963**	.951**	1	.958**
P-value	0.321	0.328	**0.010**	0.080	0.483	0.410	0.928	0.567	0.454	0.756	**0.000**	**0.000**		**0.000**
avg n-inj PPT	-0.100	-0.102	-.463*	-0.263	-0.199	-0.195	-0.127	-0.164	-0.049	0.140	.936**	.965**	.958**	1
P-value	0.635	0.636	**0.023**	0.204	0.340	0.360	0.555	0.444	0.816	0.505	**0.000**	**0.000**	**0.000**	

Table 7 (Continued)

Not Injured	NRS	VAS	VRS 5	Mankoski	PCS total	PCS rum	PCS mag	PCS help	PSFS total	BRS total	avg inj PDT	avg inj PPT	avg n-inj PDT	avg n-inj PPT
NRS	1	.604**	.371*	.369*	.490**	.467**	.327*	.487**	-0.138	-0.263	-0.164	-0.160	-0.187	-0.186
P-value		**0.000**	**0.017**	**0.019**	**0.001**	**0.002**	**0.033**	**0.001**	0.391	0.088	0.295	0.305	0.230	0.233
VAS	.604**	1	.494**	.499**	.342*	.348*	0.170	.351*	-0.191	-.356*	0.006	-0.007	-0.070	-0.046
P-value	**0.000**		**0.002**	**0.001**	**0.031**	**0.028**	0.295	**0.026**	0.245	**0.024**	0.973	0.966	0.667	0.780
VRS 5	.371*	.494**	1	.480**	.368*	.425**	0.201	.329*	-0.088	-0.070	0.069	0.062	0.071	0.043
P-value	**0.017**	**0.002**		**0.002**	**0.018**	**0.006**	0.208	**0.036**	0.595	0.662	0.669	0.700	0.661	0.790
Mankoski	.369*	.499**	.480**	1	.336*	.357*	0.210	0.310	-0.112	-0.103	-0.001	-0.031	-0.111	-0.087
P-value	**0.019**	**0.001**	**0.002**		**0.034**	**0.024**	0.194	0.051	0.502	0.527	0.996	0.850	0.494	0.594
PCS total	.490**	.342*	.368*	.336*	1	.912**	.835**	.942**	-0.148	-0.285	-0.009	-0.011	-0.073	-0.080
P-value	**0.001**	**0.031**	**0.018**	**0.034**		**0.000**	**0.000**	**0.000**	0.355	0.064	0.955	0.942	0.640	0.610
PCS rum	.467**	.348*	.425**	.357*	.912**	1	.634**	.785**	-0.038	-.382*	-0.185	-0.178	-0.249	-0.248
P-value	**0.002**	**0.028**	**0.006**	**0.024**	**0.000**		**0.000**	**0.000**	0.812	**0.011**	0.235	0.254	0.107	0.109
PCS mag	.327*	0.170	0.201	0.210	.835**	.634**	1	.722**	-0.150	-0.134	0.172	0.174	0.144	0.129
P-value	**0.033**	0.295	0.208	0.194	**0.000**	**0.000**		**0.000**	0.348	0.393	0.269	0.264	0.357	0.410
PCS help	.487**	.351*	.329*	0.310	.942**	.785**	.722**	1	-0.210	-0.200	0.060	0.045	-0.009	-0.017
P-value	**0.001**	**0.026**	**0.036**	0.051	**0.000**	**0.000**	**0.000**		0.188	0.199	0.702	0.775	0.953	0.912
PSFS total	-0.138	-0.191	-0.088	-0.112	-0.148	-0.038	-0.150	-0.210	1	0.048	-0.053	-0.045	-0.077	-0.062
P-value	0.391	0.245	0.595	0.502	0.355	0.812	0.348	0.188		0.764	0.741	0.778	0.634	0.702
BRS total	-0.263	-.356*	-0.070	-0.103	-0.285	-.382*	-0.134	-0.200	0.048	1	.341*	.332*	.378*	.368*
P-value	0.088	**0.024**	0.662	0.527	0.064	**0.011**	0.393	0.199	0.764		**0.025**	**0.030**	**0.013**	**0.015**
avg inj PDT	-0.164	0.006	0.069	-0.001	-0.009	-0.185	0.172	0.060	-0.053	.341*	1	.986**	.923**	.933**
P-value	0.295	0.973	0.669	0.996	0.955	0.235	0.269	0.702	0.741	**0.025**		**0.000**	**0.000**	**0.000**
avg inj PPT	-0.160	-0.007	0.062	-0.031	-0.011	-0.178	0.174	0.045	-0.045	.332*	.986**	1	.923**	.955**
P-value	0.305	0.966	0.700	0.850	0.942	0.254	0.264	0.775	0.778	**0.030**	**0.000**		**0.000**	**0.000**
avg n-inj PDT	-0.187	-0.070	0.071	-0.111	-0.073	-0.249	0.144	-0.009	-0.077	.378*	.923**	.923**	1	.956**
P-value	0.230	0.667	0.661	0.494	0.640	0.107	0.357	0.953	0.634	**0.013**	**0.000**	**0.000**		**0.000**
avg n-inj PPT	-0.186	-0.046	0.043	-0.087	-0.080	-0.248	0.129	-0.017	-0.062	.368*	.933**	.955**	.956**	1
P-value	0.233	0.780	0.790	0.594	0.610	0.109	0.410	0.912	0.702	**0.015**	**0.000**	**0.000**	**0.000**	

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Discussion

From the results altogether, all pain scales had some form of positive correlation, regardless of how data was sorted for interpretation. Therefore, all of the pain scales consistently and accurately assess pain intensity in and can be used in the clinical setting. For consistent measurements and accurate assessment, once a pain scale is selected it should be consistently used. While the subjective pain scales were moderate to high correlations to each other and separately the algometric measurements were highly correlated to each other, there were few correlations connecting the subjective pain scales to the algometry measurements – only VRS-5 in collegiate athletes, men, and injured subgroups. Thus, only the first hypothesis of the study is partly accepted – pain ratings from subjective pain scales were consistently significantly correlated to one another but did not consistently correlate to the algometry measurements. From these results, algometry measurements cannot be used to form a quantified value for pain level experienced – especially when the pain is not being directly caused by an external stimulus. One may still be able to use algometry measurements as a form of measuring progression of specific treatments due to repeated measures using algometry with pathologies that include point specific tenderness, as seen with Kregel et al and van Wilgen et al [39,43].

When reviewing the results between collegiate athletes and non-collegiate athletes, collegiate athletes' pain ratings on the NRS were consistently higher while also rating themselves as less functional than non-collegiate athletes. One potential reason why collegiate athletes rated themselves as less functional than non-collegiate

athletes were that the activities they chose when they completed the PSFS were more difficult than those chosen by non-collegiate athletes. For example, collegiate athletes with shoulder pain often provided task examples on the PSFS such as 'throwing a football' while non-collegiate athlete participants with shoulder pain included activities that were often categorized under activities of daily living i.e. 'putting away dishes'. However, throwing a football is a more complex task that often requires more effort to be exerted than putting away dishes. Another potential explanation surfaces with the research completed by Simon and Docherty (2014)[53], who found that collegiate athletes had a higher number of injuries as well as more severe injuries than non-collegiate athletes which led to long term limitations of exercise, activities of daily life, and overall decrease in health-related quality of life. Based on the differences seen between collegiate athletes and non-collegiate athletes in the current study, there is potential that the limitations the former collegiate athletes were experiencing per Simon and Docherty began to occur prior to terminating their athletic careers rather than after athletic participation ceased.

While not statistically significant, collegiate athletes consistently tolerated higher forces applied within the algometry measurements, as seen consistently with the current literature [34,46,47]. Thus, the second hypothesis of the study is accepted by athletes having higher pain thresholds and tolerances. There are several different theories in the current literature as to why athletes have higher pain thresholds and tolerances than non-athletes. It is commonly agreed upon that during and directly following exercise, pain modulation is seen via acute exercise induced analgesia from

endogenous opioid systems within the body[13,33,46]. It is unknown for people who exercise on a regular basis if there are long term adaptations, regarding their pain tolerance and their pain modulation ability. Several studies found that athletes had higher pain tolerances and/or enhanced conditioned pain modulation abilities compared to sedentary or active controls[29,33,46,47,54]. There were also studies that found no differences between athletes and sedentary or active controls regarding pain tolerances and conditioned pain modulation[29]. Additionally, the mechanisms of how athletes may have higher pain tolerances and augmented pain modulation abilities is unclear[13,29,33,46,55]. The most common theory is that exercise causes the release of generalized endogenous pain modulatory mechanisms, potentially via hypothalamic pituitary adrenal axis and baroreflex-mediated analgesia[29,46,54]. Furthering that theory, Flood suggested that repeated bouts of exercise causes a strengthening of the neural pathway of pain modulation to explain why athletes have higher pain modulation than sedentary[46]. The concept is similar to how people sweat more and sooner when they adapt to warmer environments. Deroche found that athletes are better at mentally ignoring pain and the more athletes ignore pain during activity the higher their pain tolerance goes and it improves their pain modulation ability[47]. A similar theory surfaced within the systematic review by Tesarz, that successful athletes that compete at a higher level do so by athletic selection process, where the athletes who can naturally tolerate more pain tend to be more successful in higher level competition athletics[29]. It is difficult to ascertain why collegiate student-athletes have higher pain thresholds and tolerances due to this study's experimental design since it was not a

priority of the investigation but it is possible that the increased algometric thresholds tolerated by the collegiate athletes could be due to enhanced pain modulation.

Pain catastrophizing had low to moderate correlations to pain scales more consistently in the non-collegiate athlete group thus demonstrating how pain catastrophizing does influence pain tolerances, as also seen in current literature [34,46]. Similar results have also been seen in other studies like Sullivan et al (2000), where male collegiate athletes were found to have the lowest PCS score, followed by female collegiate athletes then sedentary males and sedentary females, respectively[34]. Comparing the findings from this study to Sullivan et al (2000), that total values from the PCS are very close regarding the collegiate athletes but differ regarding non-collegiate athletes (Current study: collegiate athletes 15.7±9.7, non-collegiate athletes 14.0±10.0 and Sullivan: collegiate athletes 17.1±7.3, sedentary 20.0±9.1). The differences between the values of non-collegiate athletes and sedentary between the two studies may be due to differences in population composition because our non-collegiate athlete subgroup included club athletes, recreational athletes and active participants. Pain catastrophizing is present in both populations as seen with similar scores between both groups, but collegiate athletes tolerate or have found coping mechanisms to deal with pain catastrophizing more than non-collegiate athletes, which may explain why there are more consistent correlations between pain scales and PCS in non-collegiate athlete populations. In another study that examined demolition derby participants, they found that there was much lower prevalence of neck pain from whiplash in the demolition derby participants compared to the amount

of whiplash patients from motor vehicle collision accidents [56]. A potential theory, called the price of doing business, demonstrates the derby demolition participants expected and had accepted the risk and pain associated with their activity. In other literature, it has been seen that pain acceptance specifically decreases pain levels[57-59]. These differences in mentality seen in the demolition derby participants may be the reason why they have less severe symptoms that resolve sooner than individuals who are in motor vehicle collisions.

There were no significant differences between gender seen in this study, which continues to demonstrate the conflicting results found in current literature [34,60-62]. While it was not statistically significant, men tolerated more force (N) applied during algometric measurements consistently compared to women in this study, which is congruent with current literature[41,62]. Additionally, men had higher but not statistically different ratings on the pain catastrophizing scales compared to women, apart from PCS helplessness subcategory rating. However, pain scales were more consistently correlated to the PCS total and helplessness scores with women. Therefore, even though men had higher ratings of pain catastrophizing, it did not affect their subjective pain ratings/ pain scale values. Women's pain catastrophizing scores were connected to their subject pain ratings, even though they had lower pain catastrophizing scores than men. This may demonstrate that women are more affected by pain catastrophizing than men. However, there is not a clear consensus in current literature regarding gender differences with pain catastrophizing. From Sullivan et al (1995), when the PCS scale was created and validated, women were

found to have higher PCS results than men[10]. While Sullivan et al. (1995), contradicts the results from our study, Sullivan et al (2000) and Sullivan et al (2002) found similar PCS values to our study and resulted in no significant differences between gender[10,34,63]. Additionally, studies completed by Otto, Emery, and Cote (2019) and Schrooten, Karsdorp, and Vlaeyen (2012) did not find significant differences between gender and pain catastrophizing – all using Sullivan (1995) PCS [10,61,62]. There were no significant correlations between any of the PCS scores and any of the algometry measurements. These results demonstrate that pain catastrophizing influences subjective pain ratings when rating pain in general rather than when rating pain concurrently with nociceptive stimulus applied. In another study conducted by Halls and Davies where collegiate athletes were compared to non-collegiate athletes, they found no significant differences in pain perception and affect of pain[60]. However, there was statistically significant difference between the collegiate athletes and non-athletes[60]. Female non-athletes having the highest pain rating and were the most affected by the painful procedure [60]. It is likely then athletic participation is a confounding variable when examining pain catastrophizing and pain response in female subjects. With inconsistent findings in literature, research needs to continue to investigate if there is a relationship between gender, pain catastrophizing, subjective pain ratings and algometric measurements.

There is a difference between being in pain and being injured. When subjects identified themselves as injured, they had higher pain ratings (PR) compared to non-injured with NRS, VAS, and Mankoski scale. However, there was not a similar decrease

in PDT, PPT, or increase PR averages in injured people. When a person mentally shifts from being in pain to being injured, there is a change in their status. This mentality change may explain why the injured subgroup has higher pain ratings on subjective measures that were incongruent with objective measures. Within the injured group, only the VRS-5 was connected to PCS total, PCS helplessness, and algometry measurements. These correlations may be seen due to the VRS-5 scale being relatively general compared to the other pain scales, being based on a 5-point scale rather than a 10-point scale. There were more consistent correlations between all of the pain scales and the PCS total and rumination scores within the non-injured group. The study by Deroche et al (2011) suggests that repeated exposure to painful stimulus enables people to ignore pain better and so increases pain tolerance[47]. Thus, demonstrating how people who are injured develop pain tolerances and positive coping techniques when in pain, due to necessity. Another factor may be conditioned pain modulation which is the reduction of intensity from a painful stimulus when a second stimulus is applied. These specific participants were already in pain due to an injury and so when the algometry measurements were taken, a secondary painful stimulus was applied[64]. Additionally, when the data was reviewed, 69% of the injured group were collegiate athletes. This could explain why there was not a significant difference in the algometry measurements as one would expect.

With this study there are some specific limitations. The sample size was of college students and so is a sample of convenience since the study was hosted as at a university. Working with college students, there is the potential that participants did

not fully understand the questions while completing each of the questionnaires. However, all participants were reminded that questions could be asked and the investigators were present at all data collection sessions. As well, some participants may have not had joint pain but have pain manifest in what they believe as the joint from an underlying cause, like muscle imbalance. Participants also could have been confused or misinterpreted the instructions during the algometry measurements and thus potentially skewing the data. Additionally, there is a limited amount of different sports available to sample and so data couldn't be compared regarding level of contact within the collegiate athletes' subgroup. Since there was only one primary investigator, there could not be any blindness between investigator and participants to blind from collegiate athlete status and potential injury status.

With the results found from this study, several differing branches of future research surfaces. A larger sample sized focused on different sports with varying amount of contact to determine if increased exposure to high contact positions influences athletes to have higher pain thresholds and tolerances could determine if pain tolerance is innate or something developmentally based. In current research, increased ability in pain modulation has been seen in athletes[34,46], but especially marathon runners[54,65] and so further research comparing contact based and non-contact-based sports should occur. As previous evidence has suggested, a person's mental approach to pain and other mental health factors has a significant influence on pain perception [10,34,46,57,61]. Furthermore, a longitudinal study of athletes while they are in their competitive season or off while monitoring their stress could show how

significant an individual's mentality is to pain ratings. Additionally, a longitudinal study that monitors pain thresholds and tolerances in the four years of collegiate participation to investigate if pain threshold and tolerances increase over years of participating in college athletics would yield interesting results. Another potential variable that was not investigated within this study is BMI. In some research, an increased BMI level, with a mean of 31.0±7.2 kg/m^2, is correlated with higher pain ratings and even disability ratings [58]. How BMI levels could influence pain ratings in athletes is unknown and should be investigated further. Previous literature has not consistently identified gender differences between pain perception; however, some studies have found that men report lower pain ratings than women [34,41]. While this study's results demonstrate that there are no differences between biological sex, it is a topic that should be further investigated as well.

Conclusion

From the results of the data collected, each pain scale used within the study was found to be correlated to each other consistently. Therefore, the NRS, VRS, VAS, and Mankoski scale all measure pain intensity accurately and reliably. Any four of the pain scales used in this study could be used in a clinical setting to accurately and reliable measure pain intensity with patients – including the athletic population. However, once a pain scale is chosen to be used, it should be used consistently. There was no statistical difference between gender regarding PDT, PPT, or pain rating. Both genders are influenced by pain catastrophizing which has been a significant influence in other studies in the literature but needs to be continued to be researched [34,57,61,66-69]. Additionally, being in pain and identifying as injured may cause a difference in pain ratings. With increased levels of pain ratings and pain catastrophizing in non-injured and non-collegiate athletes may demonstrate that the first major injury causes significant mental barriers to arise during the rehabilitation process.

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APPENDICES

Appendix A: Numerical Rating Scale (NRS)

Appendix A: Numerical Rating Scale (NRS)

The 11-point Box Scale (BS-11)

If a zero (0) means “no pain” and a ten (10) means “pain as bad as it could be”, on this scale of 0 to 10, what is your level of pain? Put an “X” through the number.

0	1	2	3	4	5	6	7	8	9	10

Appendix B: Visual Analogue Scale (VAS)

Appendix B: Visual Analogue Scale

Please mark where your pain is on the line below

_____

No pain Worst pain

Appendix C: Verbal Rating Scale (VRS-5)

Appendix C: Verbal Rating Score (VRS-5)

The 5-point Verbal Rating Scale (VRS-5)

Please indicate which word best describes your pain level.

- ( ) Mild
- ( ) Discomforting
- ( ) Distressing
- ( ) Horrible
- ( ) Excruciating

Appendix D: Mankoski Pain Scale

Appendix D: Mankoski Pain Scale

Mankoski Pain Scale – A Numeric Pain Intensity Scale

Please circle the number that best describes your pain level.

0	No pain	No medication needed
1	Very minor annoyance – occasional minor twinges	No medication needed
2	Minor annoyance – occasional strong twinges	No medication needed
3	Annoying enough to be distracting	Mild painkillers are effective (Aspirin, Ibuprofen, Tylenol)
4	Can be ignored if you are really involved in your work, but still distracting.	Mild painkillers relieve pain for 3-4 hours
5	Can't be ignored for more than 30 minutes.	Mild painkillers reduce pain for 3-4 hours
6	Can't be ignored for any length of time, but you can still go to work and participate in social activities.	Stronger painkillers (Codeine, Vicodin) reduce pain for 3-4 hours
7	Makes it difficult to concentrate, interferes with sleep. You can still function with effort.	Stronger painkillers are only partially effective. Strongest painkillers relieve pain (Oxycontin, Morphine)
8	Physical activity severely limited. You can read and converse with effort, Nausea and dizziness set in as factors of pain.	Stronger painkillers are minimally effective. Strongest painkillers reduce pain for 3-4 hours.
9	Unable to speak. Crying out or moaning uncontrollably near delirium.	Strongest painkillers are only partially effective.
10	Unconscious. Pain makes you pass out.	Strongest painkillers are only partially effective.

Developed by Andrea Mankoski in 1995

Appendix E: Pain Catastrophizing Scale

Appendix E: Pain Catastrophizing Scale

When I'm in pain… (Circle the best answer for each statement)

	Not at all	Mildly	Moderately	Severely	All the time
I worry all the time about whether the pain will end	1	2	3	4	5
I feel I can't go on	1	2	3	4	5
It's terrible and I think it's never going to get any better	1	2	3	4	5
It's awful and I feel that it overwhelms me	1	2	3	4	5
I feel I can't stand it anymore	1	2	3	4	5
I become afraid that the pain will get worse	1	2	3	4	5
I keep thinking of other painful events	1	2	3	4	5
I anxiously want the pain to go away	1	2	3	4	5
I can't seem to keep it out of my mind	1	2	3	4	5
I keep thinking about how much it hurts	1	2	3	4	5
I keep thinking about how badly I want the pain to stop	1	2	3	4	5
There's nothing I can do to reduce the intensity of the pain	1	2	3	4	5
I wonder whether something serious may happen	1	2	3	4	5

Appendix F: Patient Specific Functionality Scale (PSFS)

Appendix F: Patient Specific Functionality Scale (PSFS)

I am going to ask you to identify up to 3 important activities that you are unable to do or are having difficulty with as a result of your _____problem. Today, are there any activities that you are unable to do or are having difficulty with because of your _____problem?

Score each activity you are unable to do or are having difficulty with that would fall into each category

Scoring Scale (Select 1 number only for each activity listed above)

0 1 2 3 4 5 6 7 8 9 10

Unable to Perform Activity

Able to perform activity at the same level as before Injury or problem

Activity	**Score**
	0 1 2 3 4 5 6 7 8 9 10
	0 1 2 3 4 5 6 7 8 9 10
	0 1 2 3 4 5 6 7 8 9 10

Appendix G: Brief Resilience Scale (BRS)

Appendix G: Brief Resilience Scale (BRS)

Brief Resilience Scale

Please indicate which box response is most accurate to the accompanying statement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BRS 1	I tend to bounce back quickly after hard times	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
BRS 2	I have a hard time making it through stressful events	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐
BRS 3	It does not take me long to recover from a stressful event	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
BRS 4	It is hard for me to snap back when something bad happens	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐
BRS 5	I usually come through difficult times with little trouble	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
BRS 6	I tend to take a long time to get over setbacks in my life	5 ☐	4 ☐	3 ☐	2 ☐	1 ☐

Total Score: _____

Appendix H: Algometry Measurements

Appendix H: Algometry Measurements

Please hand your packet back to the researcher.

Thank you for your participation!

Anatomical Snuffbox (right)

PDT 1: _____	PPT 1: _____	Pain Rating (0-10): _____
PDT 2: _____	PPT 2: _____	Pain Rating (0-10): _____
PDT 3: _____	PPT 3: _____	Pain Rating (0-10): _____

Anatomical Snuffbox (left)

PDT 1: _____	PPT 1: _____	Pain Rating (0-10): _____
PDT 2: _____	PPT 2: _____	Pain Rating (0-10): _____
PDT 3: _____	PPT 3: _____	Pain Rating (0-10): _____

Medial Knee Joint Space (right)

PDT 1: _____	PPT 1: _____	Pain Rating (0-10): _____
PDT 2: _____	PPT 2: _____	Pain Rating (0-10): _____
PDT 3: _____	PPT 3: _____	Pain Rating (0-10): _____

Medial Knee Joint Space (left)

PDT 1: _____	PPT 1: _____	Pain Rating (0-10): _____
PDT 2: _____	PPT 2: _____	Pain Rating (0-10): _____
PDT 3: _____	PPT 3: _____	Pain Rating (0-10): _____

Erector Spinae (right)

PDT 1: _____ PPT 1: _____ Pain Rating (0-10): _____

PDT 2: _____ PPT 2: _____ Pain Rating (0-10): _____

PDT 3: _____ PPT 3: _____ Pain Rating (0-10): _____

Erector Spinae (left)

PDT 1: _____ PPT 1: _____ Pain Rating (0-10): _____

PDT 2: _____ PPT 2: _____ Pain Rating (0-10): _____

PDT 3: _____ PPT 3: _____ Pain Rating (0-10): _____

Joint Pain Site: _____ (right)

PDT 1: _____ PPT 1: _____ Pain Rating (0-10): _____

PDT 2: _____ PPT 2: _____ Pain Rating (0-10): _____

PDT 3: _____ PPT 3: _____ Pain Rating (0-10): _____

Joint Pain Site: _____ (left)

PDT 1: _____ PPT 1: _____ Pain Rating (0-10): _____

PDT 2: _____ PPT 2: _____ Pain Rating (0-10): _____

PDT 3: _____ PPT 3: _____ Pain Rating (0-10): _____