EFFICACY OF PATTERNED ELECTRICAL NEUROMUSCULAR FACILITATION AS A RECOVERY MODALITY IN ELITE LEVEL BASEBALL PITCHERS

By

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BASEBALL PITCHERS

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Abstract: *Introduction:* The purpose of this study was to investigate the efficacy of patterned neuromuscular electrical stimulation (PENS), a specific type of electrical stimulation, as a recovery modality for collegiate pitchers. PENS was compared to active recovery (AR) and a cryotherapy control group (C). *Methods:* 16 healthy, college pitchers participated in this study. Each followed their normal throwing program prescribed by their pitching coach. Prior to a bullpen, each pitcher underwent the subjective and strength assessments (Pre). The parameters evaluated included two subjective measurements: perceived soreness (PS) and perceived percent readiness (PPR); as well as three strength assessments: shoulder abduction (abd-), shoulder external rotation (ER), and shoulder abduction while internally rotated (abd-/IR). Upon completion of the bullpen, participants received one of the three recovery modalities. At 24 hours (24P) and 48 hours post throwing (48P), subjective assessments were repeated, with an assessment of strength taken at 24 hours post throwing. Each pitcher went through this process three times, until each recovery modality had been performed once. *Statistical Analysis:* One way analysis of variance and paired samples t-tests were performed to evaluate the efficacy of each of the three modalities across time, across different measures, and against each other. Tukey's HSD were performed for all significant ANOVAs. *Results:* Significant differences were observed with the subjective measures across time. PS increased from Pre to 24P and decreased to near baseline levels from 24P to 48P with the C and AR interventions. Perceived soreness decreased from Pre to 24P and again from 24P to 48P with PENS. Perceived readiness followed a similar trend, decreasing from Pre to 24P and increasing to near baseline levels at 48P with C and AR, while PENS returned to better than baseline levels at 48P. Strength assessments never achieved significance.

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CHAPTER I

INTRODUCTION

With athletes constantly striving to perform at the peak of their ability, finding the optimal form of recovery has become a crucial part of training. Athletes, as well as coaches, athletic trainers, physical therapists and strength and conditioning coaches utilize many different measures in hopes that they might return the athlete back to full strength and performance as quickly as possible following bouts of physical exertion. By improving recovery time, athletes are able to train and compete at the highest level sooner and more efficiently. The effects of high intensity activities such as pitching in baseball can cause damage to such an extent that pitchers often need several days to recover. In most cases, starting pitchers have between 5-7 days between throwing bouts to let their arm (shoulder, elbow, and wrist) recover and to train to improve performance. Pitchers spend much of their practice time allowing their body to recover and concentrate on the finite skills and mental aspects of the game.[1] More often than not, pitchers are unable to work on full effort throwing mechanics because there is not enough time between throwing bouts.[1] Short-term deficits in performance are typically caused by metabolic disturbances after episodes of high-intensity exercise.[2] Muscular soreness that lasts days after throwing can be directly attributed to skeletal muscle damage and can be observed with increased levels of intramuscular enzymes, specifically lactate, in the blood.[3]

In the event that there is not sufficient recovery after episodes of high-intensity exercise, detrimental long-term effects such as overtraining can occur.[4] Furthermore, since much of pitching centers around the mental aspect, a pitcher's subjective opinion of how they feel while throwing is just as important as how well their arm has recovered physiologically.[1]

Modalities such as cryotherapy, massage, active recovery, stretching, and electromuscular stimulation (ES), are among some of the most popular recovery modalities used by clinicians.[4] These therapeutic measures can be used independently or they can be used in combination for a synergistic effect. For instance, some athletes prefer to incorporate stretching into their active recovery program. Other athletes may choose to go through an active recovery and then apply a form of cryotherapy, such as ice, afterwards. Ice is a commonly used recovery modality, although supporting research is lacking.[4] Active recovery is popular because research has shown that it aids with post-exercise lactate removal by increasing blood flow and allowing an influx of leukocytes.[1,4] More recently, a specific form of EMS known as patterned electrical neuromuscular stimulation (PENS) has been introduced. PENS replicates the electromyographic firing patterns of muscle groups during specific functional movements and actions.[5] Most of the research conducted with PENS has been limited to the lower body, but research has shown that functional patterns of EMS can improve functional performance.[5] It has even been shown that PENS may be capable of enhancing the recovery of nerves damaged due to stroke and improving firing rates of muscles after the vascular incident.[6]

Since PENS has been shown to be effective at mimicking the patterns of specific motions, it is possible that it could be a reliable substitute for active recovery, especially for pitchers. In order for pitchers to target the most affected part of their body (the shoulder) after pitching, they need to focus on movements that involve the rotator cuff and scapular stabilizers.[7] After throwing approximately 100 pitches during an outing, a pitcher may experience pain and discomfort performing an active recovery of the shoulder. By using PENS, the athlete can stay in a pain-free position and still receive the benefits of patterned neuromuscular stimulation to the shoulder girdle.

The purpose of this study was to test the effectiveness of PENS in comparison other to other recovery modalities such as cryotherapy and active recovery. We hypothesized that PENS would be a more effective means of recovery. In addition, we were able to test different recovery measures on Division I athletes during their normal training program. This population is a proper representation of elite athletes.

RESEARCH QUESTION:

- Is Patterned Neuromuscular Stimulation (PENS) a reliable form of recovery modality when compared with contemporary methods (active recovery and cryotherapy) in high-level pitchers?

HYPOTHESES:

- H_0: PENS is not an effective and reliable form of recovery modality in comparison to other methods previously used.
- H_1: PENS is an effective and reliable form of recovery modality for baseball pitchers in comparison to other methods previously used.
- H_2: PENS is capable of decreasing soreness, increasing perceived readiness, and returning an athlete to baseline strength levels more effectively than active recovery and cryotherapy.

ASSUMPTIONS OF THE STUDY:

- We assumed that subjects adhered to the testing protocol set forth by the researchers and did not use alternate forms of treatment on their own.
- We assumed that subjects provided 100% effort during their daily throwing programs.
- We assumed that subjects completed the same form of daily preventative arm care exercises to prevent injury during the course of the study.
- We assumed that there was no delay in regularly scheduled throwing sessions due to weather or other environmental conditions that could give more recovery time between sessions.
- We assumed that subjects disclosed any prior upper extremity injuries that had occurred in the past 12 months.
- We assumed that subjects provided full effort during strength testing assessments.
- We assumed that subjects answered truthfully on all subjective based questioning.
- We assumed that instruments used during the study (PENS machine, Keiser pneumatic resistance machine) were in working order and reliable.
- We assumed that there would be no adverse reactions to any of the recovery methods used.

LIMITATIONS OF THE STUDY:

- The Keiser Functional Trainer has not been validated as a strength measurement tool through previous research.
- The results of this study will only be applicable to a similar population.
- Since college athletes are being used as subjects, class and practice schedules are subject to change and may coincide with testing times.

DELIMITATIONS OF THE STUDY:

- Subjects were required to pass a pre-participation physical examination by a physician.
- Subjects must have not had any injury to the upper extremity that required surgery or prevented participation for more than 3 months.
- Subjects must have had a minimum of 2 years of experience pitching at a high level (high school, travel baseball, college).
- Subjects were required to complete a pre-season pitcher's screening consisting of a strength and ROM assessment.
- Subjects performed a uniform set of preventative arm care exercises each day under the supervision of an athletic trainer prior to throwing.
- Strength measurements were taken by the same certified athletic trainer to provide consistent, objective data.
- Instead of a non-treatment control group, the 'control' group received cryotherapy after throwing. This preventative measure was established so that study subjects could continue in their activities without additional insult.

DEFINITION OF TERMS:

- Neuromuscular stimulation (NMES): the use of electrical stimulation of a nerve to cause contraction of a muscle.
- Electromuscular stimulation (ES): the use of electrical stimulation directly over a muscle to stimulation a contraction of the muscle.
- Patterned electrical neuromuscular stimulation (PENS): form of NMS that mimics high performance sports specific electromuscular patterns of functional movements.[8]

- Phase duration: the time between the beginning of an electrical pulse and the end of said pulse.[9]
- Triphasic: pulse pattern in which three overlapping phase durations occur progressively in order to create a short, quick, movement of a joint.[10]
- Bullpen session: throwing session in which pitchers throw a short game simulation comprised of between 50-100 pitches.
- Flush exercise: low intensity exercise performed in order to increase blood flow and remove lactic acid from muscles, usually after a bout of high intensity exercise.
- Modality: a therapeutic method or device having curative powers.[9]
- Break test: strength test in which subject is put into the desired position and resistance is gradually applied until they are no longer able to hold that position.

CHAPTER II

REVIEW OF LITERATURE

There has been extensive research performed on the use of recovery modalities, but very little of that research has occurred with high level athletes. This is most likely because elite athletes are more reluctant to change their training regimens.[4] Since elite athletes respond differently to training stimuli than untrained individuals, researchers should target elite athletes as subjects so that an accurate representation of this group can provide to the existing pool of knowledge. After the review of the literature, only one study examined recovery modalities in elite athletes and fortunately, this study was performed on baseball pitchers.[11]

Pitching Biomechanics

The pitching motion is a combination of several different motions that all focus on generating velocity. There are several different accepted breakdowns of the pitching sequence, but all are very similar. Perhaps the most widely accepted sequence was introduced by Dillman, Fleisig, and Andrews. Here, the trio proposed that the pitching motion was composed of 6 individual phases: the windup, stride, arm cocking, arm acceleration, arm deceleration, and follow through. During the first three phases (windup, stride, arm cocking) the pitcher begins the motion and puts their arm and body in position to begin the natural progression towards home plate. Once the arm acceleration phase begins, the body begins to rotate towards the target and the shoulder internally rotates. The speed of the ball during arm acceleration changes from approximately 4 miles per hour (mph) to upwards of 85 mph in just a matter of feet.[12] A large force is needed to generate this change in velocity, but once the ball has been released a larger force is needed to slow the arm during the deceleration phase. This requires a violent eccentric force from the infraspinatus and teres minor on the posterior aspect of the shoulder originating off of the scapula and inserting into the humeral head. Rotation velocities of 7,000° per second are generated during the acceleration phase. Internal rotation of the shoulder slows to zero degrees per second during the deceleration phase, which lasts only a few hundredths of a second.[12] This force, repeated on average of 100 times per outing, causes considerable amounts of micro trauma and increased lactate production in the involved musculature.

Lactate Removal

Elite athletes (eg. college pitchers) focus on training and performing at a very high-intensity. This high-intensity activity causes an increase in lactate concentration in skeletal muscle. This increase has been linked to muscle fatigue, driving the belief that muscle recovery is based on the removal of lactate from the body. However, recent evidence has not supported the removal of lactic acid as a proper indicator of recovery. Several studies found that performance did not increase even after lower lactate concentrations were found.[4,13]

Furthermore, other studies showed an increase in performance even though there was no change in lactate concentrations.[14-17] Szymanski found that even high concentrations of blood lactate (which do not occur even with the high-intensity of repeated pitching) return to baseline levels within 1 hour post activity.[1] It is important to differentiate muscle and blood lactate. Muscle lactate hosts a half-life of 9.5 minutes where blood lactate has a half-life of 15 minutes, meaning muscle lactate is removed from the body more rapidly than blood lactate.[18] These results show that the act of using a flush workout or modality to remove lactate from the body may be unnecessary and that lactate removal is not a proper indicator of recovery.[4,19] Also, the creation of lactate and the related soreness is most likely produced by the body to provide a tangible form of protection by discouraging an individual from placing further stress on that specific body part.[20]

Delayed Onset Muscle Soreness

Delayed onset muscle soreness is another factor that is believed to be causative factor in decreased performance and delayed recovery. Many researchers have examined the cause and recovery from exercise-induced soreness associated with delayed onset muscle soreness (DOMS). The exact mechanism of DOMS is not well understood, but it typically occurs following bouts of high-intensity activity in which a large eccentric component occurs. There is a high release of enzymes (creatine kinase [CK] and lactate dehydrogenhase [LDH]) during eccentric contractions. This is caused by higher amounts of tension in muscle fibers throughout eccentric contractions as compared to the preceding concentric contraction. That tension is believed to be the cause of exercise-induced muscle damage and the resultant soreness.[3] It is common belief that repeated exposure to high intensity training, especially focusing on the eccentric component, would make skeletal muscle adapt and avoid the onset of DOMS from similar activity in future bouts.[1,19] On the contrary, research suggests that there is a similar efflux of CK and LDH after high-intensity bouts even after repeated bouts.[3,21,22] The recovery and return to full strength after a DOMS inducing session can take several days; therefore a modality that enhances recovery from exercise-induced muscle damage could be beneficial to high-level athletes.[1,4]

In pitchers, there is a large eccentric force applied to the muscles that perform external rotation of the shoulder. This occurs during the deceleration phase of the throwing motion after the ball has been released. The external rotators then aggressively contract to slow the arm down. The movement of the arm during the throwing motion has been regarded as the most high velocity movement of the body in sports. It has been reported that the arm can move upwards of 7,000 degrees/second in high level pitchers, equivalent to almost 20 complete revolutions in 1 second.[7,23] Following the concentric motion, an eccentric contraction is needed to counterbalance that velocity by external rotators and scapular stabilizers. This motion is performed upwards of 100-200 times per outing and creates ample opportunity for exercise-induced muscle damage to occur.

Cryotherapy

Most of the research regarding recovery modalities has been centered on cryotherapy. Overall, cryotherapy has been accepted as an effective method of decreasing pain, soreness, and spasm after injury or high-intensity exercise.[24] Cryotherapy works by lowering the temperature of tissue and therefore lowering the metabolic rate of muscle, preventing tissue hypoxia. Decreasing the temperature also slows nerve conduction velocity, helping to reduce pain and spasm. Current research has been conflicted in regards to whether or not cryotherapy is effective. There is research supporting the use of cold modalities to enhance recovery by reducing pain after exercise or injury.[4,11,25] Conversely, many studies suggest that cryotherapy is ineffective at alleviating pain, along with DOMS, soreness, and spasm, when compared with a control group.[11,26-28] This may be attributed to a different methods and materials used in different studies.[29] In untrained individuals, there was no increase in rate of strength recovery with the use of cryotherapy when compared to a control group.[11] The same results were found when elite athletes were utilized as well.[4] Additionally, only small efforts have been made to examine the use of cryotherapy with baseball pitchers.[29] One of the studies performed found an increase in performance and decrease in muscle fatigue with the use of ice between innings of a baseball game. The shoulder was cooled off using 3 minutes of cryotherapy followed by 5 minutes of rewarming prior to returning to throwing.[29] This is not the ideal method of testing recovery, especially with a baseball pitcher because it is not realistic to ice a pitcher between every inning. However, it does show a possible positive effect of cryotherapy encouraging recovery. Another study involving elite baseball pitchers suggests that ice provided some strength recovery with shoulder abduction, internal rotation at 0 degrees, and external rotation at 0 degrees, but it was only apparent 24 hours post application and not immediately. Strength recovery for internal and external rotation at 90 degrees could be seen immediately after the application of ice when compared to non-icing groups. When coupled with light shoulder exercise, there was a synergistic effect that resulted in improvements of strength but still an increase in muscle soreness over the first 24 hours, most likely due to the onset of DOMS.[11] In summary, cryotherapy is a controversial method of recovery, especially in relation to DOMS. It has yet to be determined with confidence whether it creates a negative or positive effect. The current research based around its use in baseball has been relatively beneficial, suggesting that it could be a viable option as a recovery method for pitchers.

Active Recovery

Another form of recovery modality that has been a well-researched yet controversial method is the use of active recovery. The term 'active recovery' can include a wide range of different forms of activity. Often times it refers to a cool down period consisting of a light jog and a thorough stretch immediately following exercise. Several studies failed to find a significant difference in recovery rates between active and passive recovery based on the removal of lactate and the resynthesis of glycogen stores although, as discussed earlier that lactate removal is not a valid indicator of recovery.[11] There also might be several variables responsible for insignificant levels of glycogen resynthesis, such as nutrition before and after exercise or the intensity of the cool down period. Within the literature, only one study suggested strength as a recovery variable. It found that strength returned to base line levels faster after an active recovery coupled with cryotherapy in comparison to cryotherapy.[11]

Another form of active recovery is a session of recovery exercise occurring 24-48 hours post exercise. The use of flush runs in baseball the day after throwing have been shown to alleviate soreness in the throwing arm and encourage recovery.[1,19] This is most likely due to the increase in oxygenated blood flow and muscle temperature. The increased blood flow will also bring in a high concentration of leukocytes to help assist with the recovery process. The increase in temperature from active recovery the day after high intensity might be beneficial by providing a neutral warmth in the body.[1] This suggests that active recovery does not provide an immediate significant effect, but could be beneficial over a period of 12-48 hours.

Electrical Stimulation

Electromuscular stimulation (ES) is another modality commonly used to aid in recovery with athletes. Early on, studies of ES attempting to improve strength used high-intensity stimulation to provoke uncomfortable, maximum, isometric contractions.[5] Studies suggest that the use of ES at high enough intensities to elicit a muscle contraction aid in an increase in blood flow, similar to active recovery.[4] However, it has not been supported by the few studies that have been conducted so far. The research performed in regards to overall strength gains and neurological adaptations due to the use of ES is much more extensive. One study found that the use of ES can stimulate fast-contracting units of muscle, fibers that are normally only stimulated during bouts of intense exercise. More specifically, neuromuscular stimulation (NMS) may provide a better means of targeting these fast-contracting motor units than voluntary exercise alone.[30] Other studies suggest that the use of ES to provide a tetanic or strong twitch contraction may result in a stronger voluntary contraction with no sign of muscle hypertrophy. The changes occur to the central nervous system and provide an improvement in skill and coordination at a neuromuscular level.[31] Duan et al discovered that through a 6 week ES protocol, there was a significant increase in the percentage of type 2A muscle fibers in laboratory rats. Type 2A fibers are considered a mix between slow-twitch type 1 and fatigue resistant type 2B fibers.[32] Another study found that medium-frequency alternating current electrostimulation (MFAC) created a significant increase in strength under high speed isokinetic testing. This also suggested that type 2 fast-twitch fibers benefited most from ES use.[33] Generally speaking, strength gains in type 2 muscles are only achieved through high intensity exercise. ES can achieve this more effectively because of the increased myelination of type 2 fibers that activate the motor units of muscles.[5] Since baseball pitching involves many powerful repetitions over an extended period of time, type 2 fibers in the shoulder musculature would be most beneficial.[32] However, an increase in strength does not necessarily equate to an overall improvement in functional performance.[5] In regards to neural adaptation, one study found the use of ES with one channel on an agonist and one on the antagonist was capable of replicating specific movements and increasing skill and coordination with complex movements. These strength gains were only observed with isometric contractions, but were not for tested in a dynamic mode.[31] In the 1970s, the idea of a 'Russian' stimulation was brought to the United States with claims that strength gains of 30% were possible with its use. Russian stimulation uses a similar uncomfortable waveform as early ES units, and elicited the same increases in strength at an isometric level. However, research supporting its' ability to improve performance is highly questionable.[5] Other new forms of ES with sports-specific patterns have emerged, with hopes of bridging this gap.

Patterned Electrical Neuromuscular Stimulation

By the 1990s, a specific type of ES called patterned electrical neuromuscular stimulation (PENS) had been developed and used widely in sports. PENS is a specific form of neuromuscular stimulation (NMS) that simulates healthy, high performance sports specific electromyogram (EMG) patterns of different functional movements.[8] PENS operates at a much lower carrier wave (only 50 Hz where Russian current operates at 2500 Hz) and has phase durations less than half of Russian current stimulation.[5] This allows PENS to bypass skin impedance and still produce a contraction of the muscle without causing discomfort with patients. According to the initial patent application for the Omnistim FX^2 (Accelerated Care Plus, Reno, Nevada), PENS utilizes both a biphasic and triphasic pulse-train pattern. A pulse-train pattern is a firing pattern in which overlapping phases are produced to create a ballistic, small range of motion movement. Channel

1 is connected to the agonist muscle, whereas channel 2 is connected to the antagonist muscle, both via electrodes. For a biphasic pulse-train, channel 1 will produce a pulse train (pulse duration 200 milliseconds) followed by a second pulse train produced by channel 2 (pulse duration 200 milliseconds). There is a small overlap (usually 20-40 milliseconds) in which both channels are producing their respective pulse trains at the same time. In a triphasic pulse-train, there are pulses produced by channel 1 followed by channel 2 (similar to biphasic), but before the termination of channel 2's pulse train, a second pulse train from channel 1 is produced (pulse duration 100 milliseconds).[10] This sequence of pulses creates contractions from the agonist-antagonist-agonist to recreate a small range of motion functional movement at the involved limb.[5]

PENS has been used primarily for neuromuscular re-education but has been used in populations varying from geriatrics to college athletics.[5] It has shown to be effective with atrophy reduction in postsurgical patients as well.[5] The first study focusing on the performance enhancing qualities of PENS utilized healthy college athletes and examined the effect that PENS had on increasing vertical jump over the course of a 6-week program. Although the research design was not ideal (participants were grouped based on availability during the week to avoid too many participants having to be disqualified from the study), it found a significant increase in vertical jump in subjects who used PENS during their jump when compared to those who did not.[5] This study was different than previous studies, since a functional movement was produced and the performance was measured instead of only isometric or isokinetic strength.

One of the reported disadvantages to traditional EMS strength training was the inability to translate strength gains to functional activities.[31,32,34] Pitching in baseball is a very intense, highly functional movement that requires high power movements with precise neuromuscular timing on behalf of the shoulder musculature. A respectable amount of literature suggest that the most important piece of the shoulder during the throwing motion is the musculature that surrounds and stabilizes the scapula.[7,23] There is an intricate sequence of motions by the scapula during the throwing motion and can be affected by minor alterations. In order for this sequence to occur seamlessly, scapular stabilizers should be strengthened and conditioned in the most functional way possible. Early in the rehabilitation and strengthening phases of the shoulder, simple isometric and single-plane movements are used to perform isolated strengthening. As the athlete progresses, movements become more complex involving multi-planar motions and eventually into highly-functional motions such as throwing at high velocity.[23] A primary issue with baseball players (especially pitchers) is that several days of rest are needed after a high intensity bout of throwing to allow time for the body to recover. During this period, pitchers are often unable to perform strengthening exercises to help speed up the recovery process due to a lack of pain-free range of motion.[1,11] It is possible that PENS could allow strengthening to take place via triphasic ballistic pulse trains without forcing the athlete to move in a painful motion.

Given the current understanding of PENS, there are still several questions presented by previous researchers. Yanagisawa suggested that further investigation into the mechanisms of how cryotherapy and active recovery reduce soreness and increase muscle strength following throwing is warranted.[11] Barnett stated that both cryotherapy and EMS did very little to enhance the recovery process, and that further studies utilizing elite athletes as subjects would be more useful in making inferences with research. Also, because the use of recovery modalities are becoming more prominent in athletics, more time and research needs to be dedicated to determining the efficacy of these methods.[11] Specifically, he suggested focusing studies on determining whether or not recovery modalities were capable of increasing the performance of elite athletes by allowing them to tolerate higher training intensities sooner after exercise.[4]

There is no known research over the use of the PENS producing Omnistim FX^2 with elite athletes.[8] In general, there is very little research regarding the use of PENS with any population. Accelerated Care Plus (ACP) has published a manual of different PENS protocols for baseball specific movements but has yet to back these protocols with any controlled studies. Specifically, they claim that by using the triphasic pattern trains produced by the FX2, common movements that occur while playing baseball can be simulated and strength gains can be achieved.[8]

There is a need for further research testing the efficacy of different recovery modalities, specifically active recovery, in elite level athletes. Also, there is need to investigate the use and effectiveness of PENS as a substitute to active recovery in situations in which the benefits of active recovery may not be a viable option for athletes. If PENS proved to be a suitable form of recovery modality, it could possibly in the efficacy change how athletes are able to train by allowing them to get back on the field safer and quicker after bouts of high intensity exercise.

CHAPTER III

METHODOLOGY

The subjects for this study were chosen from a convenience sample comprised of the pitchers on a Division I collegiate baseball team. Team leadership was notified and provided consent to allow their athletes to participate in the study. 16 pitchers (Mean age: 20.0 years ± 1.26 years) were asked to participate and were required to give informed consent prior to beginning the study. After gaining informed consent, the 16 subjects were randomly arranged into three groups. They remained in their respective group throughout the entire study. This study was a crossover experiment in which each group will underwent each recovery modality. The first recovery modality was the control modality (C). Instead of the traditional control, this control modality consisted of the application of an ice pack on the shoulder for 20 minutes immediately following throwing. This is to minimize the risk of subjects performing an outside treatment independently, since most pitchers will ice after they finish throwing. The second modality was active recovery (AR). This consisted of an abbreviated exercise routine performed immediately after throwing followed by the application of an ice pack for 20 minutes. The subject performed two sets of 20 repetitions of three exercises with a one-pound dumbbell or a minimal resistance rubber therapy band for resistance. The three exercises were shoulder


Figure 1


Figure 2


Figure 3

external rotation at zero degrees of shoulder abduction (Figure 1), shoulder flexion to ninety degrees with the shoulder internally rotated (Figure 2), and shoulder abduction to ninety degrees with the subjects palm facing towards the ground (Figure 3).

The subjects were monitored by a certified athletic trainer to ensure proper technique.

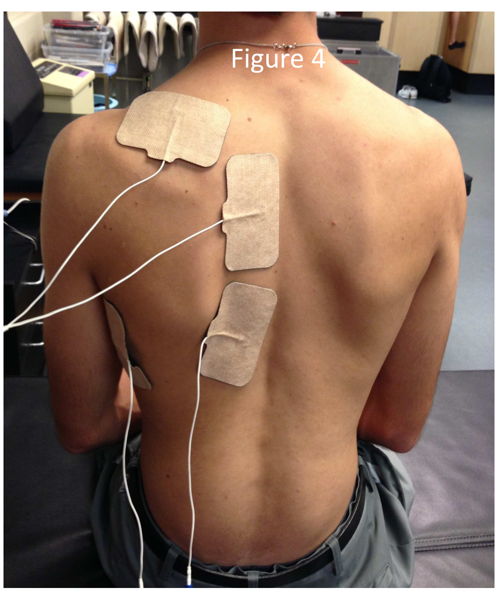


Figure 4

The final modality was the application of PENS followed by the application of an ice pack for 20 minutes (PENS). The pad placement is shown in Figure 4 and is the recommended procedure according to Accelerated Care Plus.[8] Each PENS treatment lasted for fifteen minutes and the subject was placed in a seated position with their arm in a relaxed position beside them. Once the treatment has finished, an ice bag was applied for 20 minutes.

Each subject completed each of the three modalities once. Each pitcher threw an average of 2 bullpens per week; therefore each subject was able to complete the study in two weeks.

Before each bullpen begins, each subject underwent a strength assessment and a subjective survey on their current level of soreness and their perceived percentage of readiness. The strength assessment consisted of a break test performed using a Keiser Functional Trainer (Keiser®, Fresno, CA). Subjects were tested for strength in shoulder external rotation, shoulder flexion with shoulder internally rotated, and shoulder abduction. The Keiser machine uses air pressure to increase resistance while the cable attachment is in a chosen position, so a gradual increase could be applied (Figure 5). At the point that the subject was unable to maintain their position, the resistance listed on the machine was recorded. The subjects were then asked to provide their current level of soreness on a scale of 0-10 (with 0 indicating no soreness and 10 being extreme soreness) and perceived readiness to pitch as a percentage (100% indicating complete readiness). At that point the subjects underwent their normal routine of warm-up and then complete their throwing requirements. Immediately afterwards, they received the designated modality. At twenty-four hours post treatment (24P), the strength assessment and subjective surveys were repeated and scores were documented. The subjective surveys will be repeated once more at 48 hours post treatment (48P).

Figure 5

Data Analysis

A one-way ANOVA was performed to compare the 1) difference in the measures (perceived soreness, perceived readiness, strength measurements) across times (P, 24P, 48P); 2) difference in measures across different modalities (control, active recovery, PENS); 3) difference in modalities across times; and 4) changes in modality measures over time. Tukey's HSD were performed on all comparisons to determine group differences.

CHAPTER IV

RESULTS

The purpose of this study was to determine if PENS is an effective and reliable form of recovery modality among elite level baseball pitchers when compared to other commonly used recovery modalities. 16 collegiate level pitchers (Mean age: 20.0 years ± 1.26 years) were used in this study.

A significant difference was shown with perceived soreness and percent perceived readiness when analyzed across time. Perceived soreness was shown to increase between measurements at P and 24P ($F_{(2,142)}$=9.41, p=.00) and decrease between 24P and 48P ($F_{(2,142)}$=9.41, p=.00). There was so significant difference between measurements at P and 48P. Percent perceived readiness followed a similar trend, with both comparisons showing a high level of significance (p<.001) between measurements at P and 24P, and 24P and 48P (Tables 1 and 2) There was a significant difference among perceived soreness ($F_{(2,143)}$=3.50, p<.03), and percent perceived readiness ($F_{(2,143)}$=3.25, p<.03) between the control modality and PENS (Tables 3 and 4). When comparing the difference in measures across different modalities at pre-throwing, there were no significant differences with any measures (Tables 5 and 6).

At 24P, there was no true significant difference between measures, but perceived soreness and percent perceived readiness ($F_{(2,47)}$=2.79, p=.072; $F_{(2,47)}$=2.65, p=.082) had values that were approaching significance (Tables 7 and 8). At 48P, the PENS group experienced significantly less soreness than the control group (F(2,46)=6.59, p=.003). A comparison between active and PENS was approaching significance, as well as percent perceived readiness between control and PENS (F(2,46)=3.02, p=.06) (Tables 9 and 10). No strength measures were near significance between any modalities at either 24P or 48P.

The control modality showed a significant difference across the three measure times in regards to percent perceived readiness ($F_{(2,47)}$=5.35, p=.008). This was most apparent between P and 24P ($F_{(2,47)}$=5.35, p=.013), and between 24P and 48P ($F_{(2,47)}$=5.35, p=.029) (Tables 11 and 12). For the active recovery modality across time, there was significant difference in perceived soreness between P and 24P ($F_{(2,47)}$=5.70, p=.025), and 24P and 48P ($F_{(2,47)}$=5.70, p=.009); and percent perceived readiness between P and 24P ($F_{(2,47)}$=5.67, p=.007), and 24P and 48P ($F_{(2,47)}$=5.67, p=.038) (Tables 13 and 14). PENS, similarly to the other two modality groups, showed a significant difference among perceived soreness and percent perceived readiness. Perceived soreness showed significance between P and 48 ($F_{(2,46)}$=5.92, p=.007), and 24P and 48P ($F_{(2,46)}$=5.92, p=.025). Percent perceived readiness showed significance between 24P and 48P ($F_{(2,46)}$=4.26, p=.015), only. Also, combined abduction and internal rotation strength was approaching significance ($F_{(1,30)}$=4.11, p=.052) within the PENS modality. This was the only strength measure that neared significance at any point across all groups (Tables 15 and 16).

Table 1: Overall Measures x Time

	Mean	SD	95% CI	ANOVA
Perceived Soreness				
Pre	1.42	1.32	1.03, 1.80	$F_{(2,142)}$=9.41***
24P	2.10	1.70	1.61, 2.60	
48P	0.89	0.96	.61, 1.18	
Percent Perceived Readiness				
Pre	93.65	9.61	90.86, 96.44	$F_{(2,142)}$=12.92***
24P	82.73	15.95	78.10, 87.36	
48P	93.55	9.47	90.77, 96.33	
External Rotation Strength+				
Pre	25.71	4.42	24.42, 27.01	$F_{(2,142)}$=.11
24P	25.40	4.73	24.02, 26.77	
Combined Internal Rotation and Abduction Strength+				
Pre	25.49	31.76	16.17, 34.82	$F_{(1,94)}$=1.63
24P	19.59	4.29	18.34, 20.84	
Abduction Strength+				
Pre	21.85	3.87	20.72, 22.99	$F_{(1,94)}$=.36
24P	21.37	3.91	20.81, 22.41	

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 2: Measures v. Time Tukey HSD

	Measure 1	Measure 2	Mean Diff.	Std. Error	95% CI
Perceived Soreness					
	Pre	24P	-0.68*	0.28	-1.35, -.03
	Pre	48P	0.52	0.28	0.14, 1.19
	24P	48P	1.21***	0.28	.55, 1.87
Percent Perceived Readiness					
	Pre	24P	10.92***	2.46	5.08, 16.76
	Pre	48P	0.09	2.48	-5.78, 5.96
	24P	48P	-10.82***	2.48	-16.69, -4.95

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 3: Differences in Measures x Modality

Modality	Mean	SD	95% CI	ANOVA
Perceived Soreness				
Control	1.81	1.54	1.27, 2.26	$F_{(2,143)}$=3.50*
Active	1.56	1.50	1.13, 2.00	
PENS	1.06	1.17	.72, 1.40	
Percent Perceived Readiness				
Control	86.75	15.16	82.35, 91.15	$F_{(2,143)}$=3.25*
Active	89.40	13.62	85.44, 93.35	
PENS	93.40	9.00	90.78, 96.01	
External Rotation Strength+				
Control	25.31	5.29	23.42, 27.23	$F_{(2,95)}$=.35
Active	25.37	3.93	23.95, 26.78	
PENS	26.18	4.53	24.55, 27.82	
Combined Internal Rotation and Abduction Strength+				
Control	19.89	4.81	18.15, 21.62	$F_{(2,95)}$=1.01
Active	28.06	38.42	6.79, 13.21	
PENS	20.45	4.47	18.84, 22.06	
Abduction Strength+				
Control	22.46	4.21	20.94, 23.98	$F_{(2,95)}$=1.24
Active	21.03	3.84	19.64, 22.41	
PENS	21.29	3.57	20.00, 22.58	

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 4: Measures v. Modality Tukey HSD

	Measure 1	Measure 2	Mean Diff	Std. Error	95% CI
Perceived Soreness					
	Control	Active	0.25	0.29	-.43, .93
	Control	PENS	.75*	0.29	.07, 1.43
	Active	PENS	0.50	0.29	-.18, 1.18
Percent Perceived Readiness					
	Control	Active	-2.65	2.63	-8.87, 3.57
	Control	PENS	-6.65*	2.63	-12.87, -.43
	Active	PENS	-4.00	2.63	-10.22, 2.22
External Rotation Strength+					
	Control	Active	-.05	1.15	-2.80, 2.70
	Control	PENS	-.86	1.15	-3.61, 1.89
	Active	PENS	-.82	1.15	-3.56, 1.94
Combined Internal Rotation and Abduction Strength+					
	Control	Active	-7.17	5.63	-20.57, 6.23
	Control	PENS	-.56	5.65	-13.96, 12.84
	Active	PENS	6.61	5.63	-6.79, 20.01
Abduction Strength+					
	Control	Active	1.43	0.97	-.88, 3.75
	Control	PENS	1.17	0.97	-1.14, 3.48
	Active	PENS	-.26	0.97	-2.05, 2.57

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* $p<.05$

** $p<.01$

*** $p<.001$

Table 5: Differences in Pre Measurements Across Different Modalities

	Mean	SD	95% CI	ANOVA
Perceived Soreness				
Control	1.56	1.50	.76, 2.36	$F_{(2,47)}$=.36
Active	1.19	0.91	.70, 1.67	
PENS	1.50	1.51	.70, 2.30	
Percent Perceived Readiness				
Control	92.19	9.83	85.95, 97.44	$F_{(2,47)}$=.34
Active	95.00	8.37	90.54, 99.46	
PENS	93.75	10.88	87.95, 99.55	
External Rotation Strength+				
Control	26.20	1.44	23.14, 29.26	$F_{(2,46)}$=.15
Active	25.58	0.98	23.50, 27.65	
PENS	25.34	0.89	23.43, 27.25	
Combined Internal Rotation and Abduction Strength+				
Control	20.01	5.21	17.23, 22.79	$F_{(2,46)}$=.91
Active	34.11	54.09	5.29, 62.94	
PENS	21.83	3.16	20.72, 22.99	
Abduction Strength+				
Control	22.28	4.25	20.01, 24.54	$F_{(2,46)}$=.18
Active	21.45	4.27	19.18, 23.72	
PENS	21.83	3.16	20.09, 23.58	

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 6: Pre Measurements Across Different Modalities Tukey HSD

	Measure 1	Measure 2	Mean Diff.	Std. Error	95% CI
Perceived Soreness					
	Control	Active	0.38	0.47	-.77, 1.52
	Control	PENS	0.06	0.47	-1.08, 1.21
	Active	PENS	-.31	0.47	-1.46, .83
Percent Perceived Readiness					
	Control	Active	-2.81	3.45	-11.16, 5.54
	Control	PENS	-1.57	3.45	-9.91, 6.79
	Active	PENS	1.25	3.45	-7.10, 9.60
External Rotation Strength+					
	Control	Active	0.63	1.59	-3.23, 4.48
	Control	PENS	0.86	1.62	-3.06, 4.78
	Active	PENS	0.24	1.62	-3.69, 4.16
Combined Internal Rotation and Abduction Strength+					
	Control	Active	-14.10	11.25	-41.39, 13.19
	Control	PENS	-2.13	11.44	-29.87, 25.61
	Active	PENS	11.97	11.44	-15.77, 39.71
Abduction Strength+					
	Control	Active	0.83	1.39	-2.55, 4.20
	Control	PENS	0.44	1.42	-2.99, 3.88
	Active	PENS	0.38	1.42	-3.82, 3.05

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 7: Differences in 24P Measurements Across Different Modalities

	Mean	SD	95% CI	ANOVA
Perceived Soreness				
Control	2.50	1.86	1.51, 3.49	$F_{(2,47)}$=2.79
Active	2.50	1.93	1.47, 3.53	
PENS	1.31	0.95	.81, 1.82	
Percent Perceived Readiness				
Control	77.50	18.80	67.48, 87.52	$F_{(2,47)}$=2.65
Active	81.00	17.17	71.85, 90.15	
PENS	89.69	8.06	85.39, 93.98	
External Rotation Strength+				
Control	24.44	4.81	21.88, 27.01	$F_{(2,47)}$=.84
Active	25.16	4.07	22.99, 27.33	
PENS	26.58	5.28	23.77, 29.40	
Combined Internal Rotation and Abduction Strength+				
Control	19.76	4.55	17.34, 22.18	$F_{(2,47)}$=.23
Active	20.01	4.31	17.71, 22.30	
PENS	19.01	4.24	16.75, 21.27	
Abduction Strength+				
Control	22.64	4.31	20.35, 24.94	$F_{(2,47)}$=1.26
Active	20.60	3.44	18.77, 22.43	
PENS	20.88	4.05	18.72, 23.03	

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 8: 24P Measurements Across Different Modalities Tukey HSD

	Measure 1	Measure 2	Mean Diff.	Std. Error	95% CI
Perceived Soreness					
	Control	Active	0.00	0.58	-1.41, 1.41
	Control	PENS	1.19	0.58	-.22, 2.60
	Active	PENS	1.19	0.58	-.22, 2.60
Percent Perceived Readiness					
	Control	Active	-3.50	5.45	-16.71, 9.71
	Control	PENS	-12.19	5.45	-25.40, 1.02
	Active	PENS	-8.69	5.45	-21.90, 4.52
External Rotation Strength+					
	Control	Active	-.72	1.68	-4.79, 3.35
	Control	PENS	-2.14	1.68	-6.20, 1.93
	Active	PENS	-1.42	1.68	-5.49, 2.65
Combined External Rotation and Abduction Strength+					
	Control	Active	-.24	1.54	-3.99, 3.50
	Control	PENS	0.76	1.54	-2.99, 4.50
	Active	PENS	1.00	1.54	-2.74, 4.74
Abduction Strength+					
	Control	Active	2.04	1.40	-1.34, 5.43
	Control	PENS	1.77	1.40	-1.62, 5.15
	Active	PENS	-.275	1.40	-3.66, 3.11

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 9: Differences in 48P Measurements Across Different Modalities

		Mean	SD	95% CI	ANOVA
Perceived Soreness					
	Control	1.38	0.96	.86, 1.89	F(2,46)=6.59**
	Active	1.00	1.03	.45, 1.55	
	PENS	0.27	0.46	.01, .52	
Percent Perceived Readiness					
	Control	90.56	11.48	84.45, 96.68	F(2,46)=3.02
	Active	92.19	9.99	86.86, 97.51	
	PENS	98.20	3.28	96.38, 100.02	

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 10: 24P Measurements Across Different Modalities Tukey HSD

	Measure 1	Measure 2	Mean Diff.	Std. Error	95% CI
Perceived Soreness					
	Control	Active	0.38	0.30	-.36, 1.11
	Control	PENS	1.11**	0.31	.36, 1.86
	Active	PENS	0.73	0.31	-.02, 1.48
Percent Perceived Readiness					
	Control	Active	-1.63	3.21	-9.41, 6.16
	Control	PENS	-7.64	3.26	-15.55, .27
	Active	PENS	-6.01	3.26	-13.92, 1.90

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 11: Differences in Control Measures Across Time

	Mean	SD	95% CI	ANOVA
Perceived Soreness				
Pre	1.56	1.50	.76, 2.36	$F_{(2,47)}$=2.62
24P	2.50	1.86	1.51, 3.49	
48P	1.38	0.96	.86, 1.89	
Percent Perceived Readiness				
Pre	92.19	2.46	86.95, 97.42	$F_{(2,47)}$=5.35**
24P	77.50	18.80	67.48, 87.52	
48P	90.56	11.48	84.45, 96.68	
External Rotation Strength+				
Pre	26.20	5.75	23.14, 29.26	$F_{(1,31)}$=.88
24P	24.44	4.81	21.88, 27.01	
Combined Internal Rotation and Abduction Strength+				
Pre	20.01	5.21	17.23, 22.79	$F_{(1,31)}$=.02
24P	19.76	4.55	17.34, 22.18	
Abdution Strength+				
Pre	22.28	4.25	20.01, 24.54	$F_{(1,31)}$=.06
24P	22.64	4.31	20.35, 24.94	

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 12: Differences in Control Measures Across Time Tukey HSD

	Measure 1	Measure 2	Mean Diff	Std. Error	95% CI
Perceived Soreness					
	Pre	24P	-.94	0.53	-2.21, .34
	Pre	48P	0.19	0.53	1.09, 1.46
	24P	48P	1.13	0.53	-.15, 2.40
Percent Perceived Readiness					
	Pre	24P	14.69*	4.92	2.75, 26.62
	Pre	48P	1.63	4.92	-10.31, 13.56
	24P	48P	-13.06*	4.92	-24.99, '-1.13

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 13: Differences in Active Measures Across Time

	Mean	SD	95% CI	ANOVA
Perceived Soreness				
Pre	1.19	0.91	.70, 1.67	$F_{(2,47)}$=5.70**
24P	2.50	1.93	1.47, 3.53	
48P	1.00	1.03	.45, 1.55	
Percent Perceived Readiness				
Pre	95.00	8.37	90.54, 99.46	$F_{(2,47)}$=5.67**
24P	81.00	17.17	71.85, 90.15	
48P	92.19	9.99	86.86, 97.51	
External Rotation Strength+				
Pre	25.58	3.90	23.50, 27.65	$F_{(1,31)}$=.09
24P	25.16	4.07	22.99, 27.33	
Combined Internal Rotation and Abduction Strength+				
Pre	34.11	54.09	5.29, 62.94	$F_{(1,31)}$=.1.081
24P	20.01	4.31	17.71, 22.30	
Abduction Strength+				
Pre	21.45	4.27	19.18, 23.72	$F_{(1,31)}$=.39
24P	20.60	3.44	18.77, 22.43	

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 14: Differences in Active Measures Across Time Tukey HSD

	Measure 1	Measure 2	Mean Diff	Std. Error	95% CI
Perceived Soreness					
	Pre	24P	-1.31*	0.48	-2.49, -.14
	Pre	48P	0.19	0.48	-.99, 1.36
	24P	48P	1.50**	0.48	.33, 2.67
Percent Perceived Readiness					
	Pre	24P	14.00**	4.40	3.34, 24.66
	Pre	48P	2.81	4.40	-7.85, 13.48
	24P	48P	-11.19*	4.40	-21.85, -.52

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 15: Differences in PENS Measures Across Time

Measure	Mean	SD	95% CI	ANOVA Results
Perceived Soreness				
Pre	1.50	1.51	.70, 2.30	$F_{(2,46)}$=5.92**
24P	1.31	0.95	.81, 1.82	
48P	0.27	0.46	.01, .52	
Percent Perceived Readiness				
Pre	93.75	10.88	87.95, 99.55	$F_{(2,46)}$=4.26*
24P	89.69	8.06	85.39, 93.98	
48P	98.20	3.28	96.38, 100.02	
External Rotation Strength+				
Pre	25.34	3.45	23.43, 27.25	$F_{(1,30)}$=.59
24P	26.58	5.28	23.77, 29.40	
Combined Internal Rotation and Abduction Strength+				
Pre	22.14	4.37	19.72, 24.56	$F_{(1,30)}$=4.11
24P	19.01	4.24	16.75, 21.27	
Abduction Strength+				
Pre	21.83	3.16	20.09, 23.58	$F_{(1,30)}$=.54
24P	20.88	4.05	18.72, 23.03	

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

Table 16: Differences in PENS Measures Across Time Tukey HSD

	Measure 1	Measure 2	Mean Diff	Std. Error	95% CI
Perecived Soreness					
	Pre	24P	0.19	0.38	-.73, 1.11
	Pre	48P	1.23**	0.38	.30, 2.17
	24P	48P	1.05*	0.38	.11, 1.98
Percent Perceived Readiness					
	Pre	24P	4.06	2.87	-2.90, 11.02
	Pre	48P	-4.45	2.92	-11.53, 2.63
	24P	48P	-8.51*	2.92	-15.59, -1.44

+ Indicates measures recorded using Keiser pneumatic cable machine. Numerical values in these sections represent pounds per square inch (PSI).

* p<.05

** p<.01

*** p<.001

CHAPTER V

DISCUSSION

The purpose of this study was to determine if PENS, a specific type of ES, could be an effective method of recovery modality among elite level pitchers by comparing it to two other popular forms of recovery: cryotherapy and active recovery. If proven effective, it could allow pitchers to return to full activity sooner and be able to train and compete at a higher level. Yanagisawa studied the effects of different modalities when used on baseball pitchers following throwing. He suggested that the use of cryotherapy along with active recovery was more effective than other methods.[11] Active recovery has long been the most commonly used form of post-exercise recovery, although the mechanism behind which is works is still misunderstood by many. The increase in blood flow does not in fact cause an increase in the removal of blood and muscle lactate, but instead provides an increase in leukocyte concentration to begin repairing tissue damaged during exercise. Also, the increase in blood flow causes an increase in body temperature, therefore providing a thermal effect to the affected area.[11] It has been debated whether or not electrical stimulation is capable of producing muscle contractions.[30,32]

Several studies have suggested that it could be possible, and that it could mimic active recovery by increasing blood flow via muscle contractions. Furthermore, Trimble suggests that ES can trigger the fast-contracting units of muscle more effectively than voluntary contractions alone by working at a neuromuscular level.[30,31] These fast-contracting units (Type 2 muscle fibers) would make up the majority of muscle used during the pitching motion.[32] If it were possible to achieve

strength gains in these muscle fibers without inducing trauma through exercise, regeneration and recovery of these muscles may be achieved quicker than with traditional methods. The manufacturer of the triphasic current delivery produces contractions of type 2 muscle fibers in a functional, patterned sequence that closely resembles the firing patterns of voluntary exercise.[8]

Strength Measurements

Results indicated that there was no significant difference between the control, active recovery, and PENS in regards to changes in strength measures at P and 24P. There was a consistent decrease in all three strength measures from P to 24P (which was expected due to the amount of trauma occurring during throwing), but no significant difference was achieved, however abduction with internal rotation at between P and 24P in the PENS treatment was the closest that any strength measure came to reaching significance with a decrease in strength of 3.99 PSI. Overall, none of the selected modalities were more effective than the others at recovering strength within the first 24 hours after throwing. This disagrees with Trimble's claim that strength gains could be achieved in fast twitch muscles. However, this could be attributed to the fact that his study did not impose any type of high-intensity exercise to offset strength gains, unlike this one.

Subjective Measurements

Figure 6

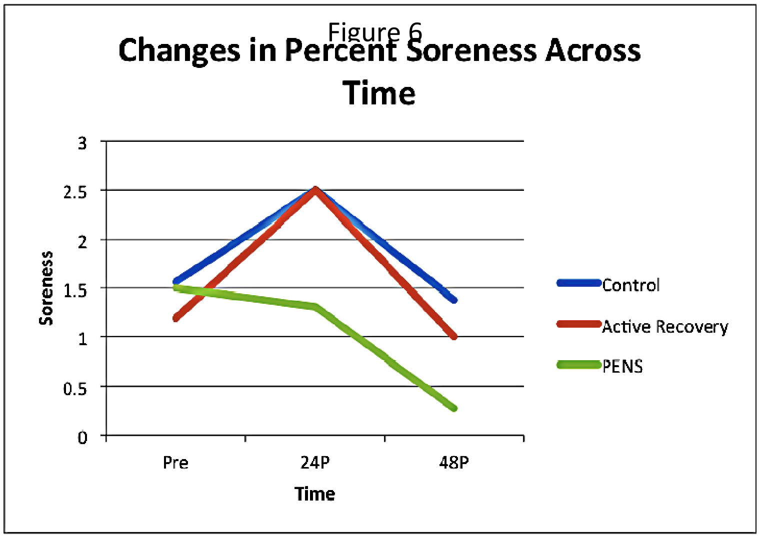
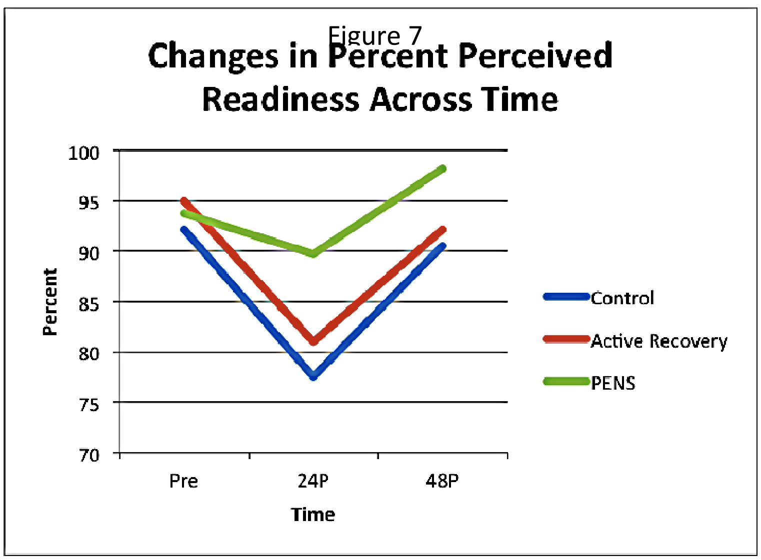


Figure 7



In regards to perceived soreness (PS) and percent perceived readiness (PPR), significance was found in several different comparisons. There was a repeated trend in which PS increased from P to 24P, and decreased and returned to near P levels at 48P. Similarly, PPR typically decreased from P to 24P and returned to close to baseline levels at 48P. When looking at the different measures across time, the average PS and PPR values were actually better at 48P than at P. This shows that, overall, the recovery modalities used were effective. Specifically, PENS produced lower PS and PPR values at all times across the study, as displayed in Figures 6 and 7. There was a significant difference when comparing PENS to the control group ($p=.03$), and although there was not significance between PENS and active recovery ($p>.05$), PENS still achieved a better overall average than active recovery. This suggests that PENS is a more effective method of recovery modality than active recovery and control at decreasing soreness and increasing perceived readiness. This is most apparent at 24 hours post throwing.

Differences in Measures Across Modalities

At P, there was no significance in any measures between any of the modalities. This was expected; as P represents the baseline value before a pitcher has thrown and received the assigned modality. At 24P, there was still no significance between modalities, but PENS had lower PS and higher PPR scores than the other two modalities. PS (p=.072) was approaching significance when comparing PENS to the control, and achieved significance at 48P. PS between PENS and active recovery was approaching significance at 48P, suggesting that over time a difference between the two may become significant. PPR approached significance between PENS and control at 48P, and overall PENS still had the best mean scores.

Differences in Measures Across Time

For all three modalities, PS and PPR values were significant between P and 24P, and again between 24P and 48P. There was not significance between P and 48P, however, this shows that P and 48P levels were similar enough to suggest that values returned to baseline levels within 48 hours after throwing. Even though this is not statistically significant, it is significant to the study because it displays overall efficacy of the modalities. Control and active recovery returned to near baseline values at 48P, but the means were slightly worse at 48P than at P. PENS, on the contrary, saw a decrease in PS values from P to 24P, and again from 24P to 48P. PS scores consistently decreased within the 48 hours after throwing, and did not follow the typical trend. The PS value at 48P for PENS was .27, compared to 1.0 for active recovery and 1.38 for the control. PENS PPR increased from 24P to 48P to a value that was 4.45% greater than baseline. This suggests that the application of PENS results in a decrease in perceived soreness within 24 hours, and not just at 48 hours post throwing similar to the other two modalities. This is noteworthy as soreness is often the main variable that affects how much a pitcher will throw on any given day. Soreness is a physiological marker representing tissue damage, and typically pitchers will train at a higher intensity if they have less soreness. In this case, a pitcher may be able to return to training at a higher intensity a full day earlier than before. Pitching in baseball hosts a very large psychological component, as well. A decreased perceived soreness would more than likely have a positive effect on the mindset of a pitcher, directly resulting in an improvement in performance.

Recommendations/Clinical Application

The results of this study showed that PENS could be a legitimate form of recovery modality among pitchers, in a subjective manner. This is beneficial because performance is affected very much so by the subjective state of the athlete. Although there is no difference in the strength component between the three methods of recovery, PS and PPR results were better with PENS assures that it has benefits in regards to recovery.

Limitations

This was the first study of its kind to use the Keiser Functional Trainer as a strength measurement tool. Although it worked fairly well at giving reliable and consistent measurements, it was dependent upon the operator to stop increasing resistance at the exact time that the subject broke their position. A digital handheld dynamometer would have eliminated this room for error. Also, using a Biodex Isokinetic Dynamometer would have given much more specific and reliable measurements. Also, due to the timing of the study, it was difficult to gain strength measurements from subjects at the same time each day due to scheduling. Coincidently, subjects were tested before practice began and before they began their routine warm-up. There were several instances in which subjects were tested later into practice or after they had completed their warm-up.

Future Research

The results of this study have created a need for further research to repeat strength measures at 48 hours post throwing and to possibly expand measurements into the 72-96 hour range to look at long-term effects. This study was conducted during the beginning stages of the spring season, so pitchers' arms were not fatigued and the incidence of overuse related soreness was very low. Conducting this same protocol later in the season after elements of fatigue and overuse were present may give a better indicator of whether PENS could be effective as a year round recovery modality.

Additionally, by taking a non-traditional approach with strength measurement instruments, the Keiser Functional Trainer showed some validity in measuring strength. There is still a level of subjectivity and operator error involved, but measurements were consistent among subjects. A study that compares strength assessments taken with the Keiser and a digital dynamometer or isokinetic dynamometer, such as the Biodex, would be necessary to fully evaluate the validity and reliability.

Finally, it may be impossible to eliminate the scheduling limitations when working with a set of elite level pitchers in their normal training setting. In the collegiate setting, factors such as class and travel schedules, changes in practice schedules, and compliance of subjects exposes a study to several unavoidable limitations.

Conclusion

In conclusion, PENS has shown to have potential to be a legitimate recovery modality when used with high level baseball pitchers. While strength wasn't fully restored in the 24 hours after throwing, the subjective components of pitching returned to near or better than baseline levels within 24-48 hours with the use of PENS post throwing. The upside to using PENS versus an active recovery is having the ability to increase blood flow via muscle contractions without moving the arm through a potentially painful range of motion. This could be very beneficial for elite level athletes because it may give them the same benefits as previously used recovery methods without exposing them to further injury.

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APPENDICES

Oklahoma State University Institutional Review Board

Date:	Thursday, November 14, 2013
IRB Application No	ED13165
Proposal Title:	Efficacy of Patterned Electrical Neuromuscular Stimulation as a Recovery Method for Collegiate Level Pitchers
Reviewed and Processed as:	Expedited

Status Recommended by Reviewer(s): Approved   Protocol Expires: 11/13/2014

Principal Investigator(s):

Elias Williams	Jennifer Volberding
170 Athletics Center	180 Colvin Center
Stillwater, OK 74078	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI, advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Cordell North (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Shelia Kennison, Chair
Institutional Review Board

INFORMED CONSENT

Project Title:

Efficacy of Patterned Electrical Neuromuscular Stimulation as a Recovery Modality in Elite Level Pitchers

Investigators:

Elias Williams, ATC
Jennifer Volberding PhD, ATC

Purpose:

This study is being conducted to address the effectiveness of three different types of recovery methods for baseball pitchers. You have been asked to participate because you are considered an elite level pitcher. This study will look to see how well these recovery methods assist in the recovery of strength and the elimination of soreness after throwing.

Procedures:

You will be asked to follow you normal routine of throwing on a day-to-day basis. You will be required to undergo a preparticipation physical, which you have already completed upon your arrival at Oklahoma State University. You will be required to undergo three different recovery methods over the period of 2-3 weeks. These methods consist of ice, ice and light exercise, and ice and a form of sensory stimulation called patterned electrical neuromuscular stimulation (PENS). PENS will be applied via electrodes to the area surrounding the shoulder blade. Each PENS treatment will last 15 minutes. Light exercise will consist of 3 common shoulder exercises and should be completed in ~5 minutes. Each ice application will last 20 minutes. The researchers will obtain strength assessments before each throwing bout and 24 hours after each recovery method is applied. A subjective survey will be completed before each bout, and again at 24 and 48 hours post treatment application. The strength tests will be machine assisted strength assessments. Example:

- Day 1: Strength assessment performed, subjective assessment completed, throwing bout performed, recovery measure performed.
- Day 2 (24 hours post): Strength assessment repeated, subjective assessment repeated.
- Day 3 (48 hours post): Subjective assessment repeated:
- Days 4,5,6: Normal throwing program will be followed. No research will be performed.
- This sequence will be repeated twice more (once for each treatment).

None of these strength assessments or light exercise should cause any discomfort to you.

Risks of Participation:

There are no known risks associated with this project that are greater than those ordinarily encountered in daily life. This study is strictly volunteer based and you may withdraw at any time. If, at any time, you experience more soreness than usual after a treatment, it will be considered an adverse reaction and you will be removed from the study. If an injury occurs needing medical attention, you will be referred to the Oklahoma State University Student Health Center, located at 1202 W. Farm Road, Stillwater, OK 74078. The Oklahoma State University Student Health Center can be contacted at (405) 744-7029. If a medical emergency occurs, you will be referred to the Stillwater Medical Center Emergency Room, located at 1323 W. 6th Avenue, Stillwater, OK 74075.

Benefits:

You may discover a new, more effective method of recovery when compared to previous methods that you have used.

Confidentiality:

You will be assigned a number at the beginning of the study, so your name will not be kept in any document. You will be given a card with your respective subject number and will be asked to bring it with you each time you report for the study. Results and measurements will be stored on a Microsoft Excel document that is encrypted and password protected. It will be stored on a computer with a password protected hard drive. Only the primary researcher will know these passwords. This computer is will be located in the Allie P. Reynolds Baseball Athletic Training Clinic throughout the completion of the study. Data will be stored for 6 months after the completion of the study and will be destroyed at that time. Data will be reported using no identifiers.

There are no foreseeable risks to maintaining the confidentiality of the participants of this study.

Compensation:

No compensation will be offered for participation in this study.

Contacts:

If at anytime you should have any questions about this study, you may contact Elias Williams, ATC, LAT, 170 Athletics Center, Stillwater, OK 74078, 325-203-0445, or Jen Volberding, Ph.D., Committee Chair, 405-744-4480.

If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

Participant Rights:

Participation in this study is completely voluntary, and you have the option to withdraw from the study at anytime without reprisal or penalty. If, during the study, you suffer an injury that affects your ability to maintain your daily throwing routine, your participation in the study may be terminated.

Signatures:
I have read and fully understand the consent form. I sign it freely and voluntarily. A copy of this form has been given to me.

_______________________ _______________
Signature of Participant Date

I certify that I have personally explained this document before requesting that the participant sign it.

_______________________ _______________
Signature of Researcher Date

Okla. State Univ.
IRB
Approved 11-14-13
Expires 11-13-14
IRB # ED-13-165

Subject:___________ PENS Active Control

Pre Throwing 24h Post Throwing 48h Post Throwing

Soreness:

One a scale of 0 to 10, with 0 indicating zero soreness and 10 indicating extreme soreness, please rate your current level of soreness.

0 1 2 3 4 5 6 7 8 9 10

Zero Soreness Extreme Soreness

Readiness to pitch:

Using a percentage scale, please indicate your readiness to pitch at full intensity currently. Zero indicates that you would not be able to pitch under any circumstance and 100% indicates full readiness to pitch.

____________%

Strength assessment:

____________ Shoulder external rotation at 0° abduction

____________ Shoulder flexion with shoulder internally rotated at 90° of abduction

____________ Shoulder abduction at 90° of abduction

VITA

Elias Carter Williams

Candidate for the Degree of

Master of Science

Thesis: EFFICACY OF PATTERNED ELECTRICAL NEUROMUSCULAR FACILITATION AS A RECOVERY MODALITY IN ELITE LEVEL BASEBALL PITCHERS

Major Field: Health and Human Performance

Biographical:

Education:

Completed the requirements for the Master of Science in Health and Human Performance at Oklahoma State University, Stillwater, Oklahoma in May 2014.

Completed the requirements for the Bachelor of Science in Health Sciences at University of Central Florida, Orlando, Florida in 2011.

Experience:

Graduate Assistant Athletic Trainer, Oklahoma State University, Stillwater, Oklahoma, June 2012-Current

Intern Assistant Athletic Training, University of Richmond, Richmond, Virginia, August 2011-May 2012

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