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Effect Of Low-Level Laser Therapy On Muscle Fatigue

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The Effect of Laser Therapy on Baseball Pitchers

A Thesis

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ABSTRACT

Pitching is one of the most demanding movements in all of sport. When muscles fatigue from pitching the mechanics of the pitcher change thus resulting in a higher chance of injury. Pitchers are always looking for ways to improve their performance by delaying fatigue. Low-level laser therapy (LLLT) has been shown to decrease muscle fatigue and limit next day soreness. The purpose of this study was to see if a LLLT treatment of the external rotators of the shoulder would increase time to fatigue using a fatiguing protocol.

13 participants volunteered for this study. Each participant would have two testing sessions: one using a LLLT treatment and one with a sham treatment with an inactive laser. Pre-test peak torque of external rotation would be measured and then the participant would complete a fatiguing protocol before completing the post-test peak torque. The fatiguing protocol consisted of a concentric and eccentric contraction of the external rotators. The participant would be declared fatigued when they had 3 trials in a row under 50% of their pre-test peak torque.

Our results showed that LLLT did not increase time to fatigue. We believe this had to do with multiple factors, such as: small sample size, no time delay between treatment, and testing, incorrect treatment dosage, and using untrained participants. Future research with these considerations will be needed to determine the effect of LLLT has on muscle fatigue.

PREFACE

I chose this research because I had no previous knowledge of LLLT and it is becoming widely used in the athletic training field. I also have a passion for baseball and working with baseball related research seemed to be a great idea. These two things in combination made this research very helpful in expanding my knowledge and I really enjoyed learning about the research process.

ACKNOWLEDGMENTS

I'd like to thank my committee (Dr. Demchak, Dr. Eberman, and Dr. Leal) for all their help and support in this endeavor. I would not be where I am today without them and their guidance. I'd also like to thank the graduate school for helping make this research possible. Lastly, I'd like to thank my family for their love and support not only throughout my time at Indiana State but throughout my education career. Without them pushing me none of this would have been possible.

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CHAPTER 1

INTRODUCTION

Baseball has many unwritten rules. One of those unwritten rules is the 100 pitch count and its effect on pitcher's fatigue level, accuracy, and velocity. It is believed that once a pitcher reaches the range of 100 pitches in a game their performance decreases and their chance of injury increases. Pitchers have tried a lot of things to try to increase their performance an durability. There is heat, ice, electrical stimulation, stretching, and much more. One thing that has not been looked into is laser therapy.

Over the past few years laser therapy has been growing in the athletic training field. It has been used for wound healing, decreasing inflammation, decreasing fatigue, and recently used to help increase performance in athletes. Also, in recent years there has been some research into what modalities to use to help aid starting pitchers in recovery. It was this study's aim to see how laser would affect starting pitchers.

Research Question

Since there is literature to support the claim that laser therapy aids in decreasing fatigue and increasing performance, we would like to explore how it would affect starting pitchers. Our research question is: Will intermittent laser therapy help decrease fatigue and increase performance (accuracy, velocity, total pitches thrown) during a simulated game?

Experimental Hypotheses

The following hypotheses will help determine the direction of our study

1. Pitchers will experience a decrease in fatigue in the last 1/3 of their outing when exposed to the laser therapy prior to throwing.
2. The average velocity of the pitches in each inning will increase when exposed to the laser therapy prior to throwing.
3. The accuracy of the pitches will increase when exposed to the laser therapy prior to throwing.
4. The total number of pitches thrown will increase when exposed to the laser therapy prior to throwing.

Definitions

Laser Therapy – Using the GameDay Super Pulsed Laser at its second setting (5-250 Hz) over the brachial artery for five minutes

Simulated Game – A game where the pitcher is simply throwing at a target without facing any live batters. We will used the model developed by Verducci (Verducci 2001).

Fatigue – We will determine fatigue using the Borg Scale after every inning to determine level of exertion. When the pitcher reaches 14 out of 16 the session will be stopped.

Assumptions

1. The subjects all know how to pitch correctly and have pitched competitively before.
2. The subjects will provide true information regarding fatigue

Delimitations

1. Healthy, starting pitchers at the collegiate (pro?) level
2. Using only the GameDay Super Pulsed Laser at its second setting
3. Using only the simulated game protocol developed by Verducci

Limitations

No known limitations have been put on this study at this time

Significance of Study

Laser is generally used post-injury or post-competition and sometimes used before to help increase performance. There is little literature on the effect it has during competition. Pitchers always look for new ways to help decrease their fatigue and improve performance. If laser therapy during competition can help pitchers achieve those goals we could change training regimens. This data could also be used in other sports during competitions to help improve performance.

CHAPTER 2

LITERATURE REVIEW

`This section will discuss the search strategies used to develop the literature review for this research project. It will also discuss the importance and relevance of laser therapy, pitching basics, current pitching therapies, and current studies.

Search Strategies

To obtain information and articles regarding this study I used the following databases: Ebscohost, PubMed, MEDLINE, and CINAHL. There were many keywords I used to find certain articles and all my information. They included: pitching, recovery, laser, therapy, blood flow, repair, effects, muscle.

Importance

Laser Therapy

Low-level laser (light) therapy was introduced in 1967, but there is a need for more evidence of its efficacy (Hashmi, Huang et al. 2010). Although some literature (Nasirian and Nasirian 2012) regarding laser therapy and its effects on wound healing is available, there is little known about the effects on muscle tissue. The effects on muscle tissue are important for athletic trainers because the majority of injuries athletic trainers see are musculo-skeletal. There is also

limited literature on the effect of laser on athletic performance. With more literature, athletic trainers and coaches could use laser to help maximize performance from their athletes.

Pitching

Pitchers and coaches are constantly trying to find a way to improve performance (velocity, accuracy, innings-pitched, etc) while decreasing injury. Fatigue often contributes to decreased performance and increased injury (Mullaney, McHugh et al. 2005). If we can find a mechanism to help decrease fatigue and recovery time, we can find a solution to increase a pitcher performance and decrease chance of injury.

Laser Therapy

General Healing

The majority of the evidence of Laser Therapy is on wound healing. The major effects of Laser with wound healing include: increased fibroblast production, increase collagen synthesis, and ATP synthesis (Pinheiro 2011). Laser has also been shown to increase blood flow, which will help the healing process (Pinheiro 2011). Low level laser therapy has been shown to increase the speed and quality of wound healing (Nasirian and Nasirian 2012). Laser has been shown to have physiological effects on wound healing. There was a reported significant increase in the amount of blood vessels and collagen fibers. This is due impart to the laser inducing he production of cytokines, which are responsible for wound healing (Nasirian and Nasirian 2012). Since low level laser can speed up the time of wound healing we assume that it can also speed up the healing time of musculoskeletal tissues. If we can speed up that healing time we can help increase the amount of work these tissue can withstand.

Musculoskeletal Therapy

In a study regarding laser and shoulder pain, the researchers regarded that laser could reduce pain and disability with musculo-skeletal injuries such as: tendinosis, tendinitis, rotator cuff disorders, impingement, and frozen shoulder (Montes-Molina, Prieto-Baquero et al. 2012). They reported positive results with laser therapy for tendinosis, tendinitis, and frozen shoulder. Impingement syndrome reported negative effects (Montes-Molina, Prieto-Baquero et al. 2012). The effectiveness of the Laser is dependent on the use of appropriate parameters. These parameters include: wavelength, power density, energy, duration, and frequency (Pinheiro 2011).

Lasers are beginning to used to treat for the purpose of pain reduction (Montes-Molina, Martinez-Rodriguez et al. 2012). Montes-Molina performed a study regarding unilateral shoulder pain being treated with interferential laser. The control group was treated with one laser while the experimental group was treated with two lasers in an interferential pattern. They measured pain intensity and shoulder disability. The patients treated with two lasers showed a statistical decrease for pain felt with abduction and external rotation from their baseline. The control group did not show any significant changes in pain from their baseline (Montes-Molina, Martinez-Rodriguez et al. 2012).

There are several physiological effects of laser therapy with a positive outcome (Pinheiro 2011). These include increased enzyme activity and a decrease in inflammation and edema. These will help reduce the amount of pain the patient is feeling during and after treatment (Montes-Molina, Prieto-Baquero et al. 2012). Low-level laser has been shown to have anti-inflammatory, analgesic, and reparative properties. This is due to its ability to increase cell metabolism, cell proliferation, and collagen synthesis. In a study it was shown to reduce edema, remodel type I and III collagen fibers, and regenerate skeletal muscle. This is because Laser

therapy promotes angiogenesis (Thais Oricchio Fedri de Souza 2011). All these positive stimulatory effects of light therapy on tissues is called “Photobiomodulation” (Larkin, Martin et al. 2012).

Class IV Laser

Lasers are classified by power level and the ability to produce eye injury, these are determined by the American National Standards Institute and the Internationals Electrotechnical Comission (Larkin, Martin et al. 2012). The laser being used for our study is a low-level laser or a class 3B laser. Class 3B emits power of 5 to 500 mW. Class 4 lasers emit power greater than 500 mW (Larkin, Martin et al. 2012). Class 4 lasers can produce an increase tissue temperature unlike low-level laser which have the same effect but have no significant effect on tissue temperature (Larkin, Martin et al. 2012). Although class 4 lasers do produce an increase in tissue temperature they also have shown to increase blood flow, making them another option to use at the clinical setting (Larkin, Martin et al. 2012).

Pulsed Laser

Currently, there is no clear consensus whether continuous wave or pulsed wave laser is better in terms of Low-Lever Light Therapy (Hashmi, Huang et al. 2010). The main type of pulsed laser therapy used for low-level therapy is super pulsed (Hashmi, Huang et al. 2010). There is an advantage of the pulsed laser because there is very little chance the tissues can be damaged due to over heating which can occur using continuous laser (Hashmi, Huang et al. 2010). This reduction in tissue heating can allow the laser to reach a higher peak power than in a continuous laser (Hashmi, Huang et al. 2010). This increase in the peak power allows the laser to penetrate deeper into the tissues (Hashmi, Huang et al. 2010). Hashmi et al. did a systematic review regarding pulsed laser and continuous laser. They found nine studies that directly

compared the two, out of the nine, six studies found that pulsed laser was more effective than continuous laser (Hashmi, Huang et al. 2010). It is possible that pulsed laser is more effective because the cells need a rest period before they can be stimulated further (Hashmi, Huang et al. 2010). It has also been found that infared laser have better skin penetration than red wavelength lasers (Leal Junior 2009).

Performance

Low-level laser therapy has been shown to interact with mitochondria and increase ATP production (Ferraresi, de Brito Oliveira et al. 2011). In a study, laser therapy was administered immediately after training sessions on the quadriceps muscles. The one rep max of the laser therapy group was significantly increased compared to the control group who did not train. It was not significantly different than the group that trained without laser therapy but the average percentage gain was higher in the laser group (Ferraresi, de Brito Oliveira et al. 2011). This article concluded that strength training in combination with laser therapy may be more beneficial than strength training alone (Ferraresi, de Brito Oliveira et al. 2011).

Most therapeutic modalities are applied after exercise but there are some studies looking at what happens if you apply laser pre-exercise. In one study, laser was applied to the quadriceps before performing the Wingate test (Leal Junior 2009). The aim of the study was to see if applying laser before exercise would decrease fatigue and muscle damage by lowering blood lactate levels. They found significant decreases in blood lactate levels in the group treated with laser. They state this could be due to the ability of the laser to prevent muscle ischemia by reducing the release of reactive oxygen species and the activity of creatine photokinase and increasing antioxidants (Leal Junior 2009). This data shows that using laser before any high

intensity exercise or competition could help decrease fatigue and would allow the muscles to recover faster between sessions (Leal Junior 2009).

Pitching

Pitching Basics

Pitching is a very demanding position in baseball, a lot of strength and stamina is needed to be a starting pitcher. Players and coaches are always looking for ways to increase performance while decreasing the chance of injury. Verducci used a simulated game in his study which helps depicts the amount of work a starting pitcher will go through. The pitchers in his study through 22 pitches (7 warm-up, 15 to batters) over eight minutes. Then the pitches are given 8 minutes of rest. They pitched until fatigued (Verducci 2001). There is a universal rule of a 100-pitch count to know when a pitcher is fatigued (Warren, Brown et al. 2011). Laser has been shown to decrease fatigue (Leal Junior, Lopes-Martins et al. 2009). In a study, subject treated with low-level laser before a workout decrease fatigue. Subjects performed as many biceps curls as possible at 75% their one rep max. There was a significant increase in total number of repetitions when the subjects received laser therapy compared to when they received placebo treatment (Leal Junior, Lopes-Martins et al. 2009). If we can decrease fatigue this will increase performance.

Fatigue

Common features of fatigue are decreased strength, motor control, and increased muscular pain (Leal Junior, Lopes-Martins et al. 2009). Physiologically, fatigue has been linked to buildup of potassium ions in the muscle fibers. There is also metabolic fatigue due to an increase in metabolites and a decrease in substrates such as ATP, creatine phosphate, and glycogen (Leal Junior, Lopes-Martins et al. 2009).When a pitcher becomes fatigued their

mechanics begin to become impaired. As mechanics become impaired the vulnerability of injury increases (Mullaney, McHugh et al. 2005). A study also described injury is possible from blood lactate levels. As the blood lactate increases, there is an increase in hydrogen ions. This increase in hydrogen ions decreases pH. A decrease in pH can impair the motor control during pitching, resulting in injury (Warren, Brown et al. 2011). Another study stated than an increase in blood lactate levels may not result in muscle fatigue (Leal Junior, Lopes-Martins et al. 2009). In that same study they showed no significant decrease in blood lactate levels in subjects treated with laser before a high intensity workout (Leal Junior, Lopes-Martins et al. 2009). Warren et al. believes that increasing blood flow will decrease the amount of hydrogen ions and improve performance (Warren, Brown et al. 2011). A study done by Tripp, Yochem, and Uhl used a fatigue protocol to determine when a pitcher or position player reached their peak fatigue. The used the Borg Scale to determine exertion. When the player reached a score of 14 out of 16 the session was stopped. They also set a limit on the total number of pitches (including warm up) to 160 (Brady L. Tripp 2007).

Current Studies

There are current studies looking at between-inning treatments to help decrease fatigue. Warren et al. used three different treatments between innings. Active recovery, which included a 6-minute jog to increase blood flow. Passive recovery, which consisted of sitting in the dugout for 6 minutes. And they used electrical stimulation between innings to increase blood flow. Their results indicated that out of the three treatments above, EMS was the best at decreasing blood lactate and improving performance (Warren, Brown et al. 2011). Verducci used icing between innings during his simulated game. The pitcher pitched his 22 pitches and then iced for 3 minutes and used 5 minutes to rewarm. The rewarming was used to increase surface temp while muscle

temp continued to decrease. This will result in increased work. Verducci explained that optimal muscle temperature in 27 degrees Celsius. As we exercise that temperature increases and we need to bring that temperature down. Verducci believes icing will do just that. At 27 degrees more work can be accomplished along with decreased fatigue and increased velocity. Verducci did see decreased fatigue and increased velocity with interval icing (Verducci 2001).

I did not find any studies regarding the effect of laser therapy on pitchers between innings or before or after a game. That is the basis of this research project. Laser has been shown to help with recovery and our goal is to see if using laser on pitchers can increase their performance while decreasing fatigue and chance of injury.

CHAPTER 3

METHODS

Design

This study was labeled as a Single Group Two Condition Experimental Design. We will randomize treatment sessions where the participant will receive laser treatment in one session and not in the other. The independent variable will be laser therapy (LT: laser therapy, C: no laser control). The dependent variables will be: Velocity, Accuracy, Level of Exertion, and Number of pitches.

Subjects

A ? number of DI and DIII pitchers from area colleges, will volunteer for this study. The subjects will all be healthy individuals.

Instruments and Measures

We used the Gameday Super Pulsed Laser at the 5-250Hz setting. The participants received the laser therapy prior to beginning their session. To measure the velocity of the pitches we used a radar gun to record the speed of every pitch. We averaged the velocity of all pitches for every inning. Accuracy was measured using a pitching practice frame with a 19” x 15” strike zone cut out and were considered accurate if they hit the target and considered inaccurate if they missed. The accuracy will be measured over three segments of the outing (first, middle, and last third). The level of exertion was measured using the Borg Scale.

Procedure

Each pitcher pitched twice, once with laser therapy and once without. We randomly assigned the order of the sample to each group. The participants receiving the intervention were treated with the laser prior to beginning their session. We treated the whole shoulder with a general scan with the laser while focusing on the rotator cuff muscles (supraspinatus, infraspinatus, subscapularis, and teres minor) and the anterior shoulder. We will use a combination of two previous pitching research studies to determine the pitching protocol. Verducci developed a simulated game protocol where the pitchers pitched 22 pitches per inning (7 warm-up, 15 to batters) and given 8 minutes of rest (Verducci 2001). Our subjects will use the same protocol. To determine the level of exertion in our subjects we used a fatigue protocol from a study done by Tripp, Yochem, and Uhl. We used the Borg Scale to determine fatigue. When the pitchers reached 14 out 16 on the scale they were stopped. They also stopped if they reached a total of 160 pitches (Brady L. Tripp 2007). The pitchers were asked about their fatigue after every inning. Accuracy was measured between laser and no laser and also over the first, middle, and last third of the outing. The velocity of all pitches per inning was collected using a radar gun and then averaged out for every inning. We also kept track of the total number of pitches thrown.

Data Analysis

Most dependent variables were analyzed using a dependent t-test (Velocity, Level of Exertion, Number of Pitches). Accuracy was analyzed using an ANOVA.

CHAPTER 4

MANUSCRIPT

Introduction

Muscle fatigue is one of the main causes of decreases in performance and increased risk of injury. One example of using this to prevent injuries and changes in performance is the 100 pitch rule. Typically after 100 pitches there is a decrease in performance as seen by a decrease in velocity and changes in pitching mechanics that could lead to an injury.

There have been multiple studies regarding the use of therapeutic modalities to decrease muscle fatigue [15], which have been extrapolated into possible ways to decrease injury risk. Verducci reported a decrease in fatigue and increase in performance with icing between innings during a mock game [14]. Additionally, Verducci also reported in a separate study an increase in the amount of work performed during a workout by icing between sets.

Recently, low-level laser therapy (LLLT) has been shown to speed up recovery post-exercise and decrease fatigue. LLLT stimulates ATP production in the muscle cells [12]. By stimulating the mitochondria; the cells produce more ATP allowing them to work harder and longer thus increasing performance. Additionally LLLT can stimulate an increase in blood flow and tissue growth [12].

External rotators (ER) of the glenohumeral joint, work concentrically through the cocking phase and then eccentrically through the follow through phase to slow down the arm making

them the muscles that fatigue the fastest. Due to the high incidence of injuries to the rotator cuff muscles in baseball pitcher the purpose of this study was to determine if treating the rotator cuff prior to exercise would decrease muscle fatigue.

Methods

This study is a single blind single group two condition experimental design with a randomization on the order of the conditions. The independent variable was LLLT and a control placebo treatment (C). The dependent variables were peak torque and number of repetitions an isokinetic machine using a concentric/eccentric shoulder fatigue protocol.

Participants

Thirteen (10 female, 3 male; Mass = 75.3± 16.0 kg Height= 170.7± 10.0cm.) healthy adults were recruited to participate in this study. Participants were included if the were 18 years old and free of injury to their dominant shoulder for the past 3 months. Participants were excluded if they had a tattoo over the treatment site due to the change in dosage from the LLLT; currently pregnant, had cancer, or a pacemaker. All inclusion and exclusion criteria were included on the health history questionnaire (HHQ).

Instrumentation

We used a Biodex Advantage isokinetic machine using a custom protocol. We used the shoulder attachment while placing the participant in 90° of shoulder abduction and 90° elbow flexion. We followed the manufacturers recommended set up for testing shoulder ER (Figure 1).

Laser Treatment

Laser treatments were completes using the MR4 laser unit with two Laser Shower emitters (MultiRadiance Medical; Solon, OH). One emitter was placed over the supraspinatus and superior portion of the Infraspinatus muscles and the other emitter was placed over the rest

of the infraspinatus (Figure 2). The emitter consisted of 6 super pulsed laser (SPL) diodes (905 nm)' 4 Infrared diodes (875 nm) and 4 red diodes (60 nm). Treatments were given simultaneously for 5 minutes at 250 Hz with an output of 40J per site. The placebo control (PC) treatment consisted of placing the emitters on the shoulder and not turning on the machine.

Procedures

Each participant came to the laboratory three times. The first meeting was informational and used to familiarize the participants on the Biodex® protocol. The participants completed the HHQ to determine eligibility. If eligible, completed informed consent form (IC) and were familiarized with the fatigue protocol on the isokinetic machine. At the end of the first session they then scheduled their two testing session which were at least 7 days apart. After the first session all participants were given a code name and number and a coin was flipped to determine the order of the treatments. Heads meant LLLT first and PC second. Tails meaning the opposite, PC first and LLLT second.

Both testing sessions were exactly the same. The participants came in and received either the LLLT or PC treatment both lasting 5 minutes. Following treatment, the participant completed a 5-minute warm up on an upper body ergometer. After the warm up, the participant was then positioned on the isokinetic machine and strapped in securely. On the isokinetic machine they completed a pre-test maximum voluntary contraction (MVC) to determine peak torque. The MVC was determined using an ER isometric contraction for 5 seconds repeated 3 times with a ten second rest period in between. After determining MVC they then completed the fatigue protocol. The fatigue protocol was a concentric/eccentric protocol to work the ER. The participant continued the protocol until they either had 3 reps in a row under 50% their peak torque or reached 25 reps. They then immediately repeated the MVC procedure.

Statistical Analysis

All analyses were done using SPSS version 18.0. The number of repetitions was analyzed using a paired samples t-test. Change score calculated between pre-test or post-test peak torques was analyzed using a t-test. A 2x2 ANOVA was used to analyze the interaction of time and LLLT. Our significance level was set at $p<.05$ a-piori.

Results

We found no significant difference (t_{12}=-1.712, p=0.113, 1-β=0.67) between LLLT (17.31±6.61) and C (15.38±7.66) in the number of repetitions to fatigue. We also found no significant change (t_{12}=0.173, p=0.866, 1-β=0.90) in peak torque between groups. (LLLT=2.68±2.11, C=2.81±1.47). We also found no interaction between time and laser ($F_{1,12}$=0.030, p=0.866, 1-β=0.053). We did find a significant difference ($F_{1,12}$= 59.0008, p<0.001, ES=0.831) between pre-test (12.99±1.25) and post-test (10.24±1.39) peak torque measures for both groups. This suggests that the protocol was effective at achieving fatigue.

Discussion

The results of our study indicated that our fatigue protocol was effective but the LLLT did not significantly change time to fatigue acutely. We did see a slight increase in the total number of repetitions, but with moderate only power (1-β= 0.67) we could draw the conclusion that a larger sample size may yield significantly different results.

LLLT has been shown to have numerous positive effects in the athletic population. Recently, research has shown positive results using LLLT to increase performance. Laser applied post exercise can decreased recovery time and increase strength gains [3]. LLLT ability to improve recovery time is thought to be related to a decrease in blood lactate levels, thus decreasing DOMS [5,6]. In another study, LLLT applied pre-exercise on the quadriceps muscle

increased maximal voluntary contraction (MVC). The MVC increased compared to the control from immediately after the LLLT up to 96 hours post treatment (Figure 3) [7]. Although our research findings were not consistent with previous literature, there is evidence that LLLT can improve performance and decrease muscle fatigue

There are several possible reasons as to why we did not find a change in MVC or increase in repetitions after the laser treatment. First our sample size was low. With a moderate power, we could assume that a larger sample size would yield different results.

Secondly, we used un-trained individuals. The other studies that found benefits of laser on performances used trained athletes. Previous literature has shown that trained individuals respond better to stress compared to untrained individuals. The literature attributes this to the fact that trained individuals showed a higher deoxygenated hemoglobin and myoglobin concentration compared to untrained. This causes fatigue in the muscle to develop more slowly thus improving performance [1]. If we had used trained individuals (pitchers) there might have been better results due to the fact they would not fatigue as quickly as our untrained sample.

The third reason is timing. We tested immediately post LLLT treatment. Many of the effects of laser take time to develop. Leal Jr et al, reported increases in MVC after 24 hours and up to 96 hours post treatment [7]. The timing of the treatment relative to the activity seems to be important. Additionally, he reported different doses had difference effects at different time intervals. Other studies that reported improvements in recovery time

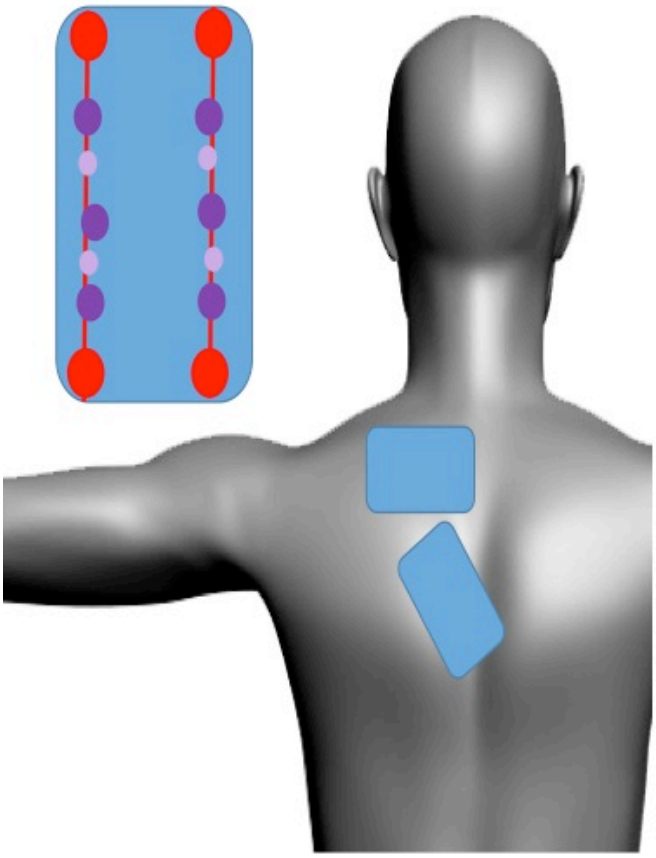
Lastly, the amount of total energy our laser protocol produced was lower than the ideal amount. Our protocol produced 40 Joules of energy at each site for a total of 80 Joules. Leal, et. al found that 30 Joules at each site was best [7]. There were 6 treatment sites, resulting in 180

Joules of total energy. A change in the protocol with either an increase in time or sites treated will produce more energy and possibly increasing the effect the laser has on the muscle cells.

Muscle fatigue in pitchers is prevalent; this is why there is the 100-pitch count rule. After 100 pitches, muscle fatigue and chance of injury increases [14]. Chance of injury increases because the muscles of the shoulder become fatigued the pitcher's biomechanics change placing added stress on ligaments and tendons. These injuries usually include rotator cuff strains and UCL ligament damage. Given the previous research, using LLLT treatment on the rotator cuff muscles should increase time to fatigue. Increasing this time to fatigue will allow the pitcher to have proper biomechanics for a longer period of time and decrease the chance of injury in the later innings of a baseball game.

Although our results did not indicate LLLT increased time to fatigue, our pilot study did provide insight into this clinical problem. A change in the sample size and protocol would be necessary for further research. As the research suggests, there is a time-delay factor with LLLT [7]. Future research may want to do a LLLT treatment session hours or even a day before testing so the laser has time to stimulate the cells and create more ATP. Future research might change the dosage to deliver the ideal 80-120 joules of power to the area. Our study did not show significant increases in time to fatigue but there was a slight increase in the mean number of repetitions so a LLLT treatment prior to pitching will not hinder performance and may have beneficial effects.

Figure 1. Biodex® Advantage Shoulder ER/IR Machine Setup.



	Emitter #	2.19E-19	2.27E-19	2.96E-19	J/photon
		3SPL	IR	Red	Total
	Photons/sec	2.85E+15	3.08E+17	2.02E+17	5.14E+17
	MOP-SPL??				
Time,sec	Irrad, W/cm2	0.000237	0.0028	0.0024	5.44E-03
300	Energy, J	0.1875	21	18	3.92E+01
	Fluence, J/cm2	0.071023	0.84	0.72	1.63E+00

Figure 2. Setup of Laser Shower Emitters (left) and Application (right)

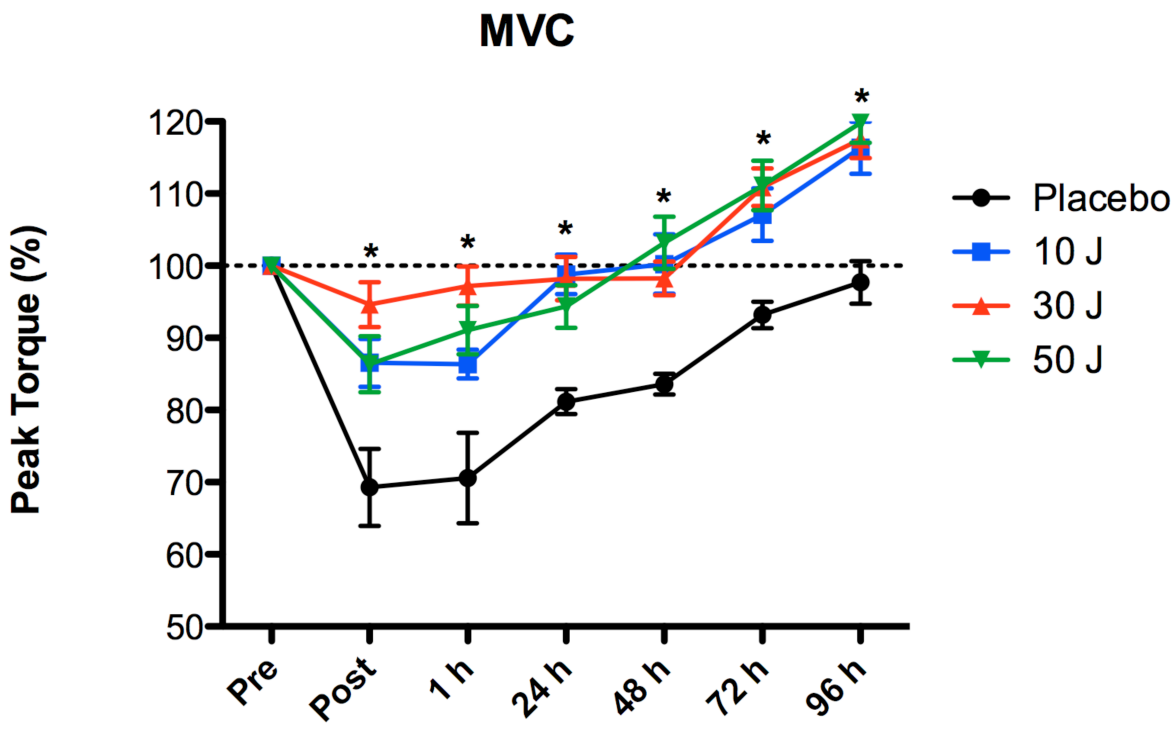


Figure 3. Effects of LLLT on MVC of the Quadriceps (presented by Dr. Leals at the APTA CSM Congress, Las Vegas, February 2014).

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APPENDIX A: RAW DATA

Age	Mass	Height	Gender	Rep_L	Rep_Con
21	100.0	164.0	2	16	11
26	50.8	155.0	2	4	3
23	55.3	165.1	2	12	10
23	97.5	188.0	1	25	19
24	81.6	172.7	2	20	25
24	81.6	185.4	1	25	21
20	70.3	165.1	2	18	12
23	71.7	175.3	2	21	25
20	90.7	170.2	2	25	25
20	72.6	170.2	2	7	4
21	56.7	165.1	2	15	13
27	86.2	182.9	1	17	20
23	63.5	160.0	2	20	12

Pre_Torque C	Post_Torque C	Pre_Torque L	Post_Torque L	torquechange C	torquechange L
14.8	13.7	16.9	15.1	1.1	1.8
8.5	4.8	6.4	5.2	3.7	1.2
6.6	5.7	8.6	4.9	0.9	3.7
19.5	17.3	20.4	19.1	2.2	1.3
14.3	11.6	13.7	10.0	2.7	3.7
13.5	9.2	13.0	11.9	4.3	1.1
11.3	7.9	12.3	8.0	3.4	4.3
10.4	7.5	12.4	5.6	2.9	6.8
17.4	11.9	17.4	13.5	5.5	3.9
7.6	7.3	10.2	7.3	0.3	2.9
11.1	6.9	9.5	7.0	4.2	2.5
20.9	18.1	21.6	23.6	2.8	-2.0
10.2	7.7	9.2	5.5	2.5	3.7