COMPARISON OF THREE DIFFERENT
POST-PITCHING RECOVERY STRATEGIES

by

Nicholas Jensen

A thesis proposal submitted to the faculty of the University of Delaware in partial fulfillments of the requirements for the degree of Master of Science in Exercise Science

Spring 2016

© 2016 Nicholas Jensen
All Rights Reserved
COMPARISON OF THREE DIFFERENT
POST-PITCHING RECOVERY STRATEGIES

by
Nicholas Jensen

Approved:
Charles B. Swanik, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved:
William B. Farquhar, Ph.D.
Chair of the Department of Kinesiology and Applied Physiology

Approved:
Kathleen S. Matt, Ph.D.
Dean of the College of Health Sciences

Approved:
Ann L. Ardis, Ph.D.
Senior Vice Provost for Graduate and Professional Education
ACKNOWLEDGEMENTS

I would like to thank my committee members Dr. “Buz” Swanik, Dr. Thomas Kaminski, Dr. Todd Royer and Aaron Struminger for helping and providing me with guidance throughout the thesis process. It has been a great task and without their help, as well as the willingness of the Delaware’s Baseball Team to participate, this study would not have been successful.
# Table of Contents

LIST OF TABLES ........................................................................ vi
LIST OF FIGURES ..................................................................... vii
ABSTRACT ................................................................................. viii

Chapter

1 INTRODUCTION ................................................................................. 1
  1.1 Purpose ...................................................................................... 6

2 METHODS ...................................................................................... 7
  2.1 Experimental Design ................................................................. 7
  2.2 Participants ............................................................................... 7
  2.3 Instrumentation ......................................................................... 8
  2.4 Procedure ................................................................................ 8
    2.4.1 Shoulder Strength ............................................................... 9
    2.4.2 Glenohumeral Internal and External Range of Motion ......... 10
    2.4.3 Infraspinatus Cross-Sectional Area .................................. 10
    2.4.4 Post-Pitching Recovery Programs ...................................... 11
    2.4.5 Scapular Exercise Routine ............................................... 12
    2.4.6 Stretching Routine ............................................................ 13
    2.4.7 Throwing Routine ............................................................. 14
  2.5 Data Analysis ........................................................................... 14

3 RESULTS ....................................................................................... 15
  3.1 Range of Motion .................................................................. 15
  3.2 Cross-Sectional Area ............................................................... 15
  3.3 Strength Measurements ........................................................... 16
  3.4 Velocity ................................................................................... 16
  3.5 Preference of Program ............................................................. 16

4 DISCUSSION ................................................................................. 17
  4.1 Limitations .............................................................................. 22
  4.2 Conclusions ............................................................................. 22

REFERENCES ................................................................................... 24
Appendix

A  LITERATURE REVIEW ................................................................. 38

B  FIGURES AND TABLES ................................................................. 64
   B.1 Stretching Routine Figures ...................................................... 64
   B.2 Strengthening Routine Figures ................................................ 70
   B.3 Strength Measurement Figures ................................................. 77
   B.4 Range of Motion Measurements Figures ..................................... 84
   B.5 Tables ................................................................. 86

C  IRB DOCUMENTS ................................................................. 96

D  IRB CONSENT FORM ................................................................. 97

E  IRB PROTOCOL ................................................................. 102

F  WEEKLY MEASUREMENT SHEET ............................................. 108
LIST OF TABLES

Table B.5.a: Combined Flexion Strength across groups........................................86
Table B.5.b: Combined extension strength across groups....................................87
Table B.5.c: Combined Scaption Strength across groups.......................................88
Table B.5.d: Combined Adduction Strength across groups.....................................89
Table B.5.e: Combined Abduction Strength across groups.................................90
Table B.5.f: Combined Internal Rotation Strength across groups.....................91
Table B.5.g: Combined External Rotation Strength across groups ...................92
Table B.5.h: Combined External Rotation ROM across groups .......................93
Table B.5.i: Internal Rotation ROM across groups.............................................94
Table B.5.j: Combined Infraspinatus CSA across groups.................................95
LIST OF FIGURES

Figure B.1.a: Shoulder Flexion Stretch ................................................................. 64
Figure B.1.b: Pectoralis Minor Stretch ................................................................. 65
Figure B.1.c: Horizontal Adduction Stretch ......................................................... 66
Figure B.1.d: Posterior Shoulder Stretch ............................................................... 67
Figure B.1.e: Internal Rotation Stretch ................................................................. 68
Figure B.1.f: Sleeper Stretches (high/mid/low) ..................................................... 69
Figure B.2.a: Table top Protraction/Retraction to the front .................................. 70
Figure B.2.b: Table Top Protraction/Retraction to the side ................................... 71
Figure B.2.c: Blackburn T-Holds and A-Holds ................................................. 72
Figure B.2.d: Blackburn Y-Holds and 90/90-Holds ............................................ 73
Figure B.2.e: Thumbtacks .................................................................................. 74
Figure B.2.f: Low row plus External Rotation ..................................................... 75
Figure B.2.g: Ultrasound Technique ................................................................... 76
Figure B.3.a: Shoulder Flexion ........................................................................... 77
Figure B.3.b: Shoulder Abduction ........................................................................ 78
Figure B.3.c: Shoulder Adduction ........................................................................ 79
Figure B.3.d: Shoulder Extension ....................................................................... 80
Figure B.3.e: Shoulder Scaption .......................................................................... 81
Figure B.3.f: Shoulder External Rotation ............................................................ 82
Figure B.3.g: Shoulder Internal Rotation ............................................................. 83
Figure B.4.a: Shoulder IR ROM ........................................................................... 84
Figure B.4.b: Shoulder ER ROM ......................................................................... 85
ABSTRACT

Context: Pitchers commonly attempt a variety of recovery methods after throwing to regain range of motion (ROM), strength, and velocity while reducing soreness. However, few prospective studies have been conducted to determine which common post-pitching recovery techniques provide the best acute restoration of patient function. Objective: To compare the effects of three different post-pitching recovery strategies in a collegiate baseball setting. Design: Randomized crossover design competed in a research laboratory, Athletic Training Room, and a baseball field. Participants: 13 collegiate pitchers at the Division 1 level between the ages of 18-22. Interventions: All participants underwent three recovery protocols (stretching, throwing, scapular-specific exercises) the day after they pitched in team scrimmages for three consecutive weeks. Ice was applied after each protocol. Recovery protocols were randomized, and measurements were taken at three different intervals (baseline, two days post-pitching, and four days post-pitching. Main Outcome Measures: The dependent variables of glenohumeral internal and external (ROM), infraspinatus Cross-Sectional Area (CSA), shoulder strength, fastball velocity, and self-reported preference were collected to determine recovery from impairments associated with pitching. Musculoskeletal ultrasound was used to measure the cross-sectional area of the infraspinatus. A handheld dynamometer was used to measure shoulder strength. A handheld velocity gun was used to measure the velocity of fastballs thrown, and a digital inclinometer was used to measure glenohumeral rotation. All data were compared using 3x2 repeated measures ANOVAs. Results: A significant
program by time effect existed for IR ROM ($F_{4,28} = .627, P = .022$). Post-hoc testing revealed that the strength group showed a significant decrease in internal rotation two days after pitching (baseline = 40.4±10.0, day 2 = 38.3± 7.0) that was greater the loss experienced after other recovery programs. This range of motion deficit returned to a value on day 4 that was improved (47.3 ±5.6) compared to baseline and the other recovery protocols, but that value was not statistically significant. A main effect for time did occur from baseline to day 4 where athletes increased strength in extension ($F_{2,20} = 7.998, P = .003$) and adduction ($F_{1,13} = 13.268, P = .002$). No significant interactions existed for CSA or Velocity. 12/13 (92%) of players preferred the stretching routine.

**Conclusions:** Performing scapular strengthening exercises on the first day after pitching resulted in significantly less internal rotation ROM on the second day after pitching but greater ROM by the fourth day when compared to stretching and throwing. Performing post-pitching recovery increased some strength measures on day four of each protocol compared to baseline. Based on the data collected in this study, the current recommendation is that a collegiate starting pitcher should complete scapular strengthening exercises on the day after pitching in order to gain full internal ROM by day four. **Word Count:** 447
Chapter 1

INTRODUCTION

The overhead throwing motion in baseball requires the upper extremity to manage large joint loads over the course of a 6-7-month season, at the professional level, and a 4-5 month season at the collegiate level. Over this span of time, starting professional pitchers, at the major league level, may throw roughly 3,000 pitches per season. In the collegiate setting, Southeastern Conference starting baseball pitchers may throw up to 1591 pitches, with an average of 1204. This accumulation of stress can lead to microtrauma and subsequent injury, with shoulder and elbow pathologies accounting for majority of surgeries in baseball players of all ages, and the most time spent on the disabled-list in professional athletes. Because pitchers have a higher upper extremity injury rate than position players, health care providers continue to develop preventative programs in this population, which include ice, stretching, light throwing, and strengthening. However, these programs differ among each organization, and appear to be failing as the number of athletes requiring surgery and time spent on the disabled list continues to increase. The limited success of these programs, despite the abundance of epidemiological data, may be a result of a lack of scientific evidence on best practices for injury prevention.

Many of these shoulder and elbow injuries are thought to occur in pitchers because of anatomical adaptations resulting from high intensity bouts of exercise. A single game may require approximately 135 pitches, and collegiate pitchers’ mechanics
remain consistent after throwing a simulated game, while their velocity may decrease in the late innings of a game. These findings are consistent with a recent study that found pitchers in the later innings experienced a significant velocity decrease. This inability to maintain velocity may occur from failure of the excitation-contraction (E-C) coupling, which causes a decline in muscle tension after eccentric exercise. E-C coupling is defined as the ability for an action potential to produce muscle contraction, and its change may be partly responsible for alterations of infraspinatus muscle function.

Eccentric exercise has been shown to produce an accumulation of hydrogen ions and inorganic phosphate leading to a decline in motorneuronal output. Gandhi et.al. found a reduction in voluntary activation or central drive to the infraspinatus, and this deactivation may lead to further injury because it creates abnormal superior humeral head migration, and ultimately subacromial or internal impingement. Therefore, the reduction of ball speed at the end of a pitching bout could be an athlete’s attempt to minimize injury risk by an involuntary decrease in throwing velocity to reduce load on the already inhibited infraspinatus. However, this mechanism to protect the shoulder is likely not adequate because glenohumeral rotation is still extremely high, reaching velocities of over 7000 deg/sec when throwing at the end of a game. These high velocities suggest that deactivation of the infraspinatus could still have detrimental consequences, impacting joint stability, or the ability of the throwing shoulder to effectively maintain proper movement through synchronous actions of the surrounding tissue.

Returning the infraspinatus to proper function before a pitcher’s next bullpen session 4 days after a pitching bout, in a collegiate setting, can be a challenge because of
the acute pathophysiologic changes that result from pitching. Initially, the posterior musculature of the rotator cuff undergoes repetitive tensile strain during an eccentric muscle contraction. “Sarcomere popping” allows for separation of the sarcomere ends releasing intramuscular calcium, resulting in fibril contraction and eventually muscle shortening. This shortening occurs 4-18 hours after throwing and is a response termed, thixotrophy, or an increase in muscular stiffness that is mediated by exercise history of the muscle. Physiologically, the repetitive eccentric contractions from pitching result in muscle edema formation shown by T2 relaxation time in magnetic resonance imaging (MRI) and by an engorgement of the muscle’s cross-sectional area (CSA). The edema after eccentric exercise then produces sensitization of the nociceptors and creates the signs and symptoms of delayed-onset muscle soreness (DOMS), which many pitchers experience 24-48 hours post pitching (1-2 days). Because thixotrophy and muscle edema both result from rotator cuff overload during pitching, these two adaptations may be related. However, no research has investigated these correlations. Furthermore, comparing throwing, stretching and scapular-specific exercises has not been studied together in the relief from DOMS in a baseball population.

If the pitcher does not recover, and continues to pitch with inadequate muscle function, other anatomical structures may have to absorb excessive loads, leading to long-term maladaptation, i.e. a tightening of both the posterior musculature and capsule. Tightening of the posterior musculature, which results from a combination of adaptive connective tissue proliferation, and subsequent shortening, along with altered descending and reflexive neural drive influencing muscle tone, may lead to glenohumeral internal
rotation deficit (GIRD), which has been shown to nearly double an athlete’s risk for injury.\textsuperscript{26,27}

GIRD has recently been defined as a deficit of 18-25° of internal rotation and/or 5-8° of total range of motion (ROM) on the dominant arm compared to the non-dominant arm.\textsuperscript{8,26,28} The development of GIRD is associated with upper extremity injury risk because it can alter humeral head kinematics and result in a secondary intra-articular pathology at the shoulder.\textsuperscript{27,29} While these adaptations are typically observed over the course of a season or a career,\textsuperscript{30,31} they have also been observed directly after a pitching session.\textsuperscript{32,33} Since thixotrophy and GIRD are modifiable by stretching within certain ranges and velocities,\textsuperscript{21,34} clinicians have used modalities aimed at increasing tissue extensibility to enhance recovery from pitching the day after a start, but have not directly looked at using stretching compared to throwing and scapular-specific exercises.

To combat these objective deficits and subjective feelings, many baseball teams have instituted uniform arm care programs for their pitchers. Conservative methods, such as cryotherapy and stretching, have traditionally been preferred modalities because they theoretically desensitize the nociceptors, reduce muscular edema, and stretch the muscles in a fibril contraction or thixotropic state, as shown by the diminished DOMS and greater range of motion. Cold water emersion has been shown to be better than no treatment for delayed-onset muscle soreness.\textsuperscript{35} However, the effect size of ice alone is not large in these studies.\textsuperscript{35}

To increase the overall treatment effect, stretching has often been a technique used in conjunction with ice to reduce of DOMS by reducing the thixotropic stiffening that occurs from the eccentric demands from pitching.\textsuperscript{22,23} Since musculature becomes
shortened at somewhere between 4 to 18 hours after eccentric activity \(^{21}\), stretching after pitching could theoretically reduce posterior shoulder tightness and increase the glenohumeral range of motion. In practice, stretching does appear to increase glenohumeral internal rotation acutely by 3.1 degrees, \(^{36,37}\) but it may only increase a person’s tolerance to the discomfort associated with stretching, allowing them to tolerate larger stretch torques. \(^{38}\) One study explained this apparent increase in range of motion or “end feel” as a familiarization with the discomfort that reduced the perceptions of pain and discomfort. \(^{39}\) Furthermore, it remains unclear whether stretching is actually effective in decreasing soreness after DOMS because little evidence supports the use of stretching alone in reducing muscular soreness after eccentric exercise. \(^{40}\) Our study will look at the potential reduction of DOMS and increase in range of motion using a combination of stretching with ice.

The final modalities used by a majority of collegiate/professional teams to promote recovery from pitching, are upper extremity weight training and throwing programs. \(^{41}\) These programs are based on anecdotal evidence and unique to each organization. The programs are the make-up of what each organization deems best for their athletes and any outside sharing may give a competitive advantage to another team. In a collegiate setting, starting pitchers generally throw every 7 days and perform upper extremity exercise routines 3 times per week. However, the order and timing of these exercises varies from team to team, as some programs cycle 3 routines per pitching week, while others have a set structure of which exercise are performed on specific days. \(^{41}\) Furthermore, a number of teams use the same routine 3 times per week, and some even find benefits throwing on the day after a pitching session to hypothetically promote
increased blood flow and to “stretch the arm out.” These proposed post-pitching programs are loosely based on previous research in DOMS recovery, which indicates that light exercise may decrease soreness within 72 hours of heavy eccentric exercise, better than ice, rest, or other modalities. However, the effectiveness of these programs has not been experimentally examined in direct relation to the baseball pitchers. No research has been done on the effects of scapular-specific exercises compared to stretching or throwing in the baseball population. Therefore, it remains unclear what type of post-pitching modalities (rest, light throwing, or strengthening) provide the best recovery for baseball pitchers.

Although each program is mandated by a pitching coach, athletic trainer or by an organization as a whole, pitchers would have a preference of a program. Players are often creatures of habit and if a player throws everyday, then they truly believe if they deviated from doing this their performance would suffer. However, if given the opportunity to compare throwing, stretching and exercising after a start day, a player may choose one strategy over the other. It is the hypothesis that players will prefer the stretching technique over the other strategies due to the immediate benefits of reduced muscular tone and decreased sensitization to nociceptors, reducing pain.

1.1 Purpose

Our purpose is to compare the effects of strengthening and throwing to the traditional ice and stretch treatment. Our hopes are to inform further research on this topic with the goal of reducing arm injuries through the baseball population by incorporating clinically scientific rationale for specific post-pitching routines.
Chapter 2

METHODS

2.1 Experimental Design

A randomized crossover study was used to examine the relationship between 6 dependent variables and the 2 independent variables. The dependent variables are muscle edema (infraspinatus), glenohumeral internal and external range of motion, shoulder strength, pitching velocity, and self-reported preference of program. The independent variable of post-pitching recovery method has three levels: stretching, throwing, and strengthening. All participants received all three conditions over a course of 3 weeks. All participants received ice after completing each condition. The independent variable of time has three levels, as data was collected at baseline, 2 days, 4 days and 7 days after pitching.

2.2 Participants

13 NCAA Division I Intercollegiate baseball players between the ages of 18-22 will participate in this study. To be eligible, athletes were a competitive baseball pitcher currently on a collegiate team and have maintained a competitive status for a year. Participants were excluded if they had any injury that would limit their ability to pitch in a competitive game or if they developed any injury that required them to skip one of the
designed pitching recovery protocols. An *a priori* power analysis was conducted using previous literature related to this methodology and with a power set at 0.80, 10 participants were needed to achieve an alpha level of 0.05.\textsuperscript{33,46} With a presumed dropout rate of 25%, it was determined that 13 participants should be included in the study.

2.3 **Instrumentation**

Area of the infraspinatus was assessed through the use of a commercially available ultrasound system (GE Logiq E, General Electric Company). A digital inclinometer (The Saunders Group Inc., Chaska, MN) was used to measure glenohumeral internal and external rotation, and a Nicholas hand-held dynamometer (Model 001160, Lafayette Instrument Company, Lafayette, IN) was used to collect shoulder strength data. A Stalker Pro 2 hand-held radar gun (Model Applied Concepts Inc., Plano, TX) was used to assess pitching velocity during live game situations. Subjects self-report which program they felt benefit them the most.

2.4 **Procedure**

This study took place at the University of Delaware and STAR Campus. Upon arrival, participants read and signed an informed consent. Each participant also filled out a health history questionnaire. After the questionnaire was completed, a baseline measurement of dominant shoulder strength, shoulder range of motion, and infraspinatus cross-sectional area was collected by the investigators. These measurements were
repeated two days post pitching and four days post-pitching. With velocity taken on day seven. After the baseline measurements were taken, each pitcher completed a self-selected warm-up and his normal pitching activities during the practice or game. During this pitching bout, the speed of the hardest three fastballs were averaged to create the baseline measure of pitching velocity. These throws did not have to be considered a strike. The pitching velocity measurement was repeated seven days post-pitching and was collected as the mean speed of the hardest three fastballs during the live session. All measurements except velocity were completed three times. The mean of those measurements were used for statistical analysis.

2.4.1 Shoulder Strength

To assess isometric shoulder strength, a handheld dynamometer was used. The motions that were tested included; shoulder internal and external rotation, shoulder abduction in the scapular plane, adduction, and flexion/extension.\(^8\) We measured shoulder muscles similar to a study performed Donatelli et al.\(^47\) Shoulder internal and external strength was measured with the subject lying supine on a table, with a bolster underneath the humerus, placing it in the scapular plane. The humerus was abducted to 45 degrees and the elbow flexed to 90 degrees. The investigator placed the dynamometer on the ulnar styloid process while the participant performed maximum internal and external rotation isometric contractions. To measure supraspinatus strength, the subject was sitting while the dominant arm is abducted to 90 degrees and 30 degrees anterior to the frontal plane (scaption) with thumbs up and the dynamometer placed on the distal
radius.\textsuperscript{47} Shoulder flexion and extension were measured with the patient sitting and arm at 0 degrees of abduction applying a flexion or extension force isometrically against the dynamometer, which was placed either on distal radius or ulnar styloid.

2.4.2 Glenohumeral Internal and External Range of Motion

To assess shoulder range of motion two clinicians were used. The participant lied supine with the humerus abducted and elbow flexed to 90 degrees. One clinician stabilized the scapula and moved the limb into external and internal ranges of motion until scapular motion was detected. Once the end range of motion was reached, the other clinician placed the inclinometer on the dorsal surface of the forearm to complete the measurement. This method was described in previous literature, and was more valid and reliable than other range of motion measurements \textsuperscript{48}.

2.4.3 Infraspinatus Cross-Sectional Area

Infraspinatus cross-sectional area was measured with the participants laying prone on a table with their arms by their sides \textsuperscript{24}. While the participant is in this position, an investigator identified the acromial angle, inferior angle of the scapula, and trigonum spinae, and marked them with a permanent marker. Following the identification of landmarks, the investigator drew a line between the acromial angle and inferior angle. Then, the investigator drew a line perpendicular to this first line that intersects the trigonum spinae. The ultrasound head was then placed on the proximal portion of this
line and slightly adjusted until a clear image of the proximal infraspinatus was present on the ultrasound unit. Once a clear image was identified, the investigator dragged the ultrasound head along the line until the recording on the ultrasound unit captured a full image of the infraspinatus. This image was then saved and used for further analysis. The methodology used was similar to that used by Oyama et al.\(^24\) The full infraspinatus image collected by the ultrasound unit was transferred to Image J software (National Institutes of Health, Bethesda, MD). Using this software, an appropriate scale was used, and an investigator traced the inside of the epimysium of the infraspinatus. This process was repeated for all images. 4 Pilot trials were collected on 4 participants, with each undergoing 2 trials per day. Intraclass correlation (ICC) were run to determine reliability of the primary investigator on CSA measurement. ICC values for all 4 individual measures (ICC\(_{3,1}\)) was .815. The values collected were then averaged to create a total value on each day. ICC\(_{3,k}\) analysis showed that the reliability of the primary investigator for measuring CSA was excellent between analysis (ICC\(_{3,k} = .977\)).

### 2.4.4 Post-Pitching Recovery Programs

Each participant was assigned a program in a block-randomized order. No more than 2-3 people in the larger group completed the same program on the same day. Programs were split as evenly as possible, but there were 13 subjects making the groups uneven.
2.4.5 Scapular Exercise Routine

Participants began the scapular exercise routine sitting upright. They placed the non-dominant hand behind their head and placed the dominant arm with the palm up between a folded towel. They reached their hands forward as far as they can go (protraction) and then dragged the towel backwards on the table while focusing on scapular retraction and depression. This retraction position will be held for 3 seconds at the end of the exercise. The next exercise maintained the same scapular cues except the arm was slid laterally instead of forward. Following the towel slides, the participants stood with full shoulder extension and their thumbs pressed against the wall. While maintaining protraction, the participants rotated their thumbs clockwise and counterclockwise to complete one repetition. The other standing exercise was a row with Theraband tubing (The Hygenic Corporation, Akron, OH). After full scapular retraction is reached from the row, an external rotation contraction was performed. This position of retraction and external rotation will be held for three seconds before returning to the starting position. All of the previously described exercises were performed in two sets of 12 repetitions. The final exercise performed was a retraction exercise in which participants lie prone and retract their shoulders until the chest is off the ground to nipple height. This position will be held for 20 seconds and will be performed twice. Strengthening exercises are pictured in Appendix B.
2.4.6 Stretching Routine

To complete the stretching routine, the athlete lied supine on a treatment table and
allowed the clinician to move their arms until they felt a stretch in the back of the
shoulder in those various positions. The investigator first performed arm circles with the
athlete in order to relax the shoulder. For the first stretch, the investigator stabilized the
scapula on the rib cage while simultaneously flexing the subject’s arm until stretch was
felt in the shoulder or inferior capsule. The second stretch also involved stabilization of
the scapula to the rib cage, but incorporated horizontal adduction of the arm instead of
flexion. The third stretch was to be a standard internal rotation stretch with the patient’s
shoulder and elbow in a 90/90 position. Both the second and third stretch were completed
twice. The fourth stretch was performed with a bolster placed under the upper back and
the arm moved into horizontal abduction, stretching the pectoralis minor. The fifth stretch
placed the patient in a side lying position and the clinician performed three passive
sleeper stretches with a bolster under the humerus, which was elevated to 115, 90, and 45
degrees. Lastly, a posterior capsule stretch was performed with the participant prone, and
the dominant arm placed underneath the stomach. One hand of the investigator’s hands
was placed underneath the shoulder while the other stabilized the scapula on the rib cage.
The first hand was used to apply a caudal force to the patient’s elbow until a stretch was
felt.
2.4.7 Throwing Routine

The participants began throwing at close-ranges and worked themselves back to 90-120 feet apart from their throwing partner. The participants were instructed to throw normally and to comfort. Roughly 25-35 throws on a linear trajectory, avoiding a high-arc were performed and the athlete worked himself back to starting position before ending the throwing session. Other cues given were for the participant to let the arm stretch itself out with loose arm action and to be aware of keeping sound mechanics. The whole routine took roughly 5-10 minutes. Pain should not have been elicited at any point. If the participant felt pain, he would terminate throwing and be removed from the study.

2.5 Data Analysis

All data analysis was conducted using SPSS version 20.0 (SPSS Inc., Chicago, IL.). Data was compared using a two-way within subjects repeated measures ANOVA with the independent variables being pitching recovery program performed and time. An a priori alpha level was set at 0.05. All significant ANOVA models were analyzed further using a Tukey HSD to examine specific changes within subjects.
Chapter 3

RESULTS

3.1 Range of Motion

A significant program by time interaction effect existed for glenohumeral internal range of motion \((F_{4,28} = .627, P = .022)\). Post-hoc testing revealed that the strength group showed a significant decrease in internal rotation two days after pitching (baseline = 40.4 ± 10.0, day 2 = 38.3 ± 7.0). This range of motion deficit returned to a value on day 4 that was improved (47.3 ± 5.6) compared to baseline, but this increase did not reach statistical significance. No significant program by time interactions were found for glenohumeral external range of motion \((F_{4,28} = .350, P = .842)\). Main effects of time \((F_{2,14} = .842, P = .452)\) and program \((F_{2,14} = 1.066, P = .371)\) also did not reach statistical significance for external rotation range of motion.

3.2 Cross-Sectional Area

No significant program by time interaction effects were observed for CSA \((F_{2,25} = 1.512, P = .240)\). Main effects for time \((F_{1,14} = .990, P = .360)\) and program \((F_{2,22} = .627, P = .544)\) were not statistically significant.
3.3  **Strength Measurements**

No significant interaction effects or main effects for program were observed for any strength measurements. However, a main effect for time did occur from baseline to day 4 for extension ($F_{2,20} = 7.998, P = .003$) and adduction ($F_{1,13} = 13.268, P = .002$). We did not observe main effects across time for scaption ($F_{1,20} = 2.209, P = .174$) flexion ($F_{2,20} = .836, P = .408$) abduction ($F_{1,13} = .491, P = .540$), internal rotation ($F_{2,20} = .288, P = .753$), or external rotation ($F_{2,20} = .028, P = .972$).

3.4  **Velocity**

No program by time interaction effect was observed for velocity ($F_{1,13} = 818, P = .392$). No significant main effects were found for velocity across time ($F_{1,12} = .806, P = .387$) or program ($F_{2,24} = 1.174, P = .326$).

3.5  **Preference of Program**

12/13 (92%) players stated stretching was the preferred method on the day after a pitching bout. One player of 13 expressed that he would rather recover by throwing the day after pitching, and another stated that he would select stretching or throwing as his recovery method with no preference between the two. 9/13 (69%) listed scapular strengthening as their second favorite program, and 9/13 (69%) listed throwing on the day after a pitching bout as their least preferred method of recovery.
Chapter 4

DISCUSSION

The most important finding of this study was that pitchers who performed a scapular strengthening program experienced a significant decrease in IR ROM on day 2 followed by a return to a value greater baseline on day 4. While this pattern was present after performing throwing the day after pitching, the decline and subsequent return to normal was not as drastic. This study is the first to report range of motion values at day 4 after pitching. Range of motion seemed to be the only variable affected by recovery program, as all strength measurements increased similarly from baseline to day 4 despite recovery method. No changes in infraspinatus cross-sectional area or throwing velocity were noted between programs or across time.

The present study found a statistically significant decrease in internal range of motion on day 2, which returned to baseline by day 4 with no significant difference in external rotation. This finding was expected because previous literature has found an acute decrease in IR ROM of approximately 9˚ immediately after a pitching bout\textsuperscript{33} and 24 hours post-pitching with no differences in ER ROM\textsuperscript{24,33}.

These deficits are similar to those experienced after eccentric exercise and have been shown to last up to three days after pitching.\textsuperscript{24,32} Our finding of a 1˚ difference from baseline, on average between the three conditions, to day 2 in IR ROM was less than that of Kibler et al.\textsuperscript{32} who found IR deficit to be at an average of 5˚ less than baseline after 2
days. The difference between these studies may exist because of the difference in IR ROM recovery between groups. In this study, athletes exhibited a 3.1° IR ROM deficit after performing the scapular strengthening exercises but a 1° increase from baseline after the stretching program. Furthermore, the 4° recovery across groups from day 2 to day 4 more closely matches deficits after pitching found by previous research. We believe that the similarity between the strength group data and previous literature may have been a result of the recovery strategies used. The pitchers in the Kibler et al\textsuperscript{32} study performed tubing exercises on the day after pitching. These exercises could have mimicked or had the same effect as the strengthening program in our study, creating the similarities in ROM. Conversely, the stretching protocol could have counteracted the typical IR loss and may be beneficial for relief pitchers, who throw on multiple days per week, to maintain ROM.

Performing scapular strengthening exercises on the day after a pitching bout resulted in a more drastic IR ROM decrease and subsequent increase compared to the other recovery programs. While IR ROM was increased on day 4, it was significantly less compared to the other programs on day 2. This difference may have been a result of the exercise-induced muscle damage that is typically produced by strength training programs. In a healthy, young population elbow extension range of motion returns to near baseline by the second day.\textsuperscript{49} These adaptations that result from muscle damage would indicate that the scapular musculature needed 48 hours to recover function after our intervention program. Despite the effects within two days observed in our study, scapular strengthening is recommended for pitchers because they lose more scapular upward rotation at 60° and 90° of glenohumeral elevation than position players.\textsuperscript{50} Our results
indicate that over the course of a week, these strengthening programs may also have a sub-acute effect on IR ROM. We speculate that the strengthening program cued the scapula to resist the abducted and protracted state that normally results post-pitching.\(^{51}\) Furthermore, a stretch of the posterior structures may have decreased the posterior capsule’s “pull” on the scapula.\(^{52}\) Better scapular position during ROM measurement on day 4 then could have relieved strain on the posterior structures and allowed for this IR increase when a passive stretch was applied.

The internal rotation decreases in this study were observed despite a lack of changes in infraspinatus CSA on day 2 or day 4 for any program. These results contrast the findings of Oyama,\(^ {24}\) who observed an increase in cross-sectional area after eccentric external rotator cuff activity. The difference between studies may have been a result of the time frame in which the CSA was measured. Because interventions were performed, we did not record infraspinatus cross-sectional area immediately after or 24hrs post eccentric exercise. Therefore, the integrity of the infraspinatus may have recovered during the time between 24 and 48 hours. Since the inflammation of the infraspinatus may have receded by day 2 and day 4 in our study, other reasons must account for the IR ROM deficits. One theory suggests that the posterior musculature may have still been in a thixotropic state after the eccentric exercise.\(^ {8,21}\) The decrease of internal rotation found on day 2 in the strength group without any change in CSA may be due to the inability of the posterior musculature to absorb the eccentric forces from pitching, placing them in a shortened position that is not related to swelling in the muscle belly. On that day 2, the stretching group slightly increased IR ROM compared to the other two modalities, but this increase may not be clinically significant. Therefore, the muscle may be in a
thixotrophic state, or the capsule and other non-contractile tissues may have absorbed some of the load. This theory is corroborated by a secondary analysis that revealed a positive correlation ($r = .644, P = .018$) between internal rotation and CSA at baseline. Since more internal rotation was correlated with greater CSA, a prolonged lack of internal rotation may limit the absorption of energy by the rotator cuff, ultimately affecting how much of the total energy that it absorbs during throwing. This lack of absorption by muscle may lead to other structures taking up the energy, such as the posterior capsule and affect it’s hypertrophy over a baseball career. The lack of hypertrophy of the infraspinatus could then affect the amount of force the muscle may absorb eccentrically. However, we did not examine the posterior capsule thickness in these athletes, so the true relationship between infraspinatus CSA and posterior capsule hypertrophy needs to be elucidated.

Significant extension and adduction strength increases over each of the 3 weeks was observed in our testing protocol despite which program was used. While not significant, strength increases were noted for all other measurements. These results were contrary to our hypotheses and surprising because previous research indicates decreases in abduction, internal rotation, and external rotation strength immediately post and 24 hours after a pitching bout.\textsuperscript{45} We also expected the recovery programs to produce varying results because a combination of active exercise and ice has been shown to reduce the strength deficits that result after pitching.\textsuperscript{45} The repeat testing of each subject may have been the cause of our results. Repeated testing has shown maximal isometric force output increases in as little as 2 testing days.\textsuperscript{53,54} Although previous research did not show an increase in glenohumeral or scapular-stabilizing strength over the course of a 6-week
strengthening program in collegiate swimmers,\textsuperscript{55,56} the strength and conditioning program that the athletes were completing could also have mildly increased strength and/or neuromuscular control. The final reason for the increase in strength across time in this study may have been that participants began to take the measurements as a competition to get beat their past score and attain the highest score on the team. This competition was not present at baseline and may have added friendly motivation to attain the highest possible strength during day 2 and day 4 testing sessions.

Like strength, no changes in velocity were observed over time. The lack of velocity difference may be a result of each pitcher being physiologically recovered each week. Furthermore, velocity at baseline and day 7 is not expected to change significantly, as a full week should be enough time to recover and maintain the same pitch speed. Velocity has been studied extensively in a baseball population.\textsuperscript{9,16,20,46} Mean fastball speed has been shown to increase at a mean of .56 mph over an 8 game span with one pitcher even improving 4.4 mph over the span of a short-season.\textsuperscript{46} However, other studies have shown a decrease in ball velocity changes within simulated or actual games.\textsuperscript{9,16,20} Since the studies that showed a change examined between-inning changes, it is hard to compare that data to our study, which only collected peak velocity during one appearance per week. These studies also had a larger throwing volume per player overall than the current study. A future study may be able to track these velocity changes based on intervention programs longitudinally.

Overall, the stretch program was preferred the most of the 3 groups for the day after a pitching bout (92%). This preference may have been due to the ease of the program that did not require the player to put forth effort during the protocol.
Furthermore, an analgesic effect has previously been noted as a result of stretching.\textsuperscript{57–59} Anecdotally, the players reported they experienced better motion post stretching than they did after throwing or performing strengthening exercises, which was confirmed objectively in the current study.

4.1 Limitations

The goal of this study was to examine recovery during an athlete’s normal (real-world) throwing conditions and not "constrain" or "control" the number of throws. Therefore, we observed a large disparity in throwing volume that could have affected our results. Follow-up studies may want to for pitch count or divide pitchers and relievers. Additionally, the ultrasound machine used to collect data did not allow a single image to capture the entire infraspinatus; therefore the muscle was broken into sections in order to be analyzed. Every effort was made to insure that these broken images matched to create a full examination of volume, and excellent reliability from pilot data showed this method was still accurate in obtaining CSA. Finally, this study lacked a large sample size, as data were only collected from one collegiate team. More participants would be needed to increase power and ultimately show significance between recovery programs across an acute time frame. Furthermore, it is still unclear if the strength increases between each group were a result of learning effect from repeat administration of strength testing.

4.2 Conclusions

This study is the first of our knowledge to compare how three different post-pitching treatment methods (stretching, throwing and strengthening) affect recovery in
the baseball population. The day after a player pitches in a game, he should be performing a recovery strategy in order to return strength, infraspinatus CSA, velocity and range of motion to baseline. The preferred condition was stretch, however; the results indicate that performing scapular exercises on the first day after pitching resulted in increased internal range of motion by the fourth day when compared to stretching and throwing. Performing any of the three strategies increased strength over a 3-week period. Based on the data collected in this study, the current recommendation is that a collegiate starting pitcher should complete scapular strengthening exercises on the day after pitching in order to gain full internal ROM by day four (bullpen day) whereas relievers may need to complete stretching programs to maintain motion for potential consecutive outings. Future research should look at the combination of strategies over a longer period of time and determine if combined stretch and strengthening programs change recovery time.
REFERENCES

1. ESPN. MLB Player Pitching Stats - 2015.


42. Coach P. Division 1 Pitching Coach. 2015:n/a.


46. Crotin RL, Bhan S, Karakolis T, Ramsey DK. Fastball velocity trends in short-


100. Andersen LL, Andersen CH, Sundstrup E, Jakobsen MD, Mortensen OS, Zebis


Appendix A

LITERATURE REVIEW

Epidemiology

An average of almost 440 Major League Baseball players were placed on the disabled list from 2002-2008 at a rate of 3.61 injuries per 1,000 exposures. This rate is alarming because it nears the current amount of injuries in high school football. Furthermore, the cost of these injuries is rising. In 2010, almost 370 million dollars were spent in 2011 for salaries of players on the disabled list, a number that has risen to an estimated 665 million dollars in 2014. Upper extremity ailments account for more than half of these injuries and represent the number one reason for time loss in these athletes.

While any impairment to a baseball player is important, a large focus is spent on pitchers because they are injured 34 percent more often than position players. If not treated properly, these injuries may end up requiring surgery, the most of which being ulnar collateral ligament (UCL) reconstruction and SLAP (Superior Labrum Anterior and Posterior) repairs. Surgery may be a good option for these injuries, as some reports indicate that more than 90% of athletes return to pre-operative levels of play. However, a more recent report suggests that these athletes do not return to play at the same level, with only 48% reaching their previous performance. Furthermore, short and long-term ramifications of surgery are still present. In the short-term, surgery increases risk of infection the potential psychological distress of taking one year to complete rehabilitation. Over a prolonged period, surgery to the shoulder or elbow can lead to
chronic upper extremity pathology such as osteoarthritis. To prevent these potential career threatening and life altering injuries, the current goal of health care professionals is to prevent upper extremity impairments in baseball pitchers.

**Injury Risk**

Reducing the number of upper extremity injuries requires a clinician to understand the adaptations that occur in elite pitchers. The nature of baseball pitching, requires eccentric-based contractions of the rotator cuff, which then the eccentric-based actions of the posterior rotator cuff undergoes subsequent damage and shortening due to the accompanying edema and release of intramuscular calcium. The infraspinatus, a main decelerator of the shoulder, has been shown to engorge after eccentric-contractions, leading to decreased internal and horizontal adduction range of motion after and 24-hour post activity. Edema, fibril shortening and muscular engorgement all may play a role in the 46% reduction in both force and voluntary activation of the infraspinatus as shown by Stackhouse et.al. Since this engorgement is occurring, ultrasound is reliable way in measuring this variable.

Diagnostic ultrasound is a quick, reliable, and easy tool for clinicians to quantify the structures that lay underneath the skin. In the present study, ultrasound will be used in order to classify any adaptations in the infraspinatus throughout the course of pitching recovery. A study performed by Oyama et al. has shown an engorgement of the infraspinatus, as measured by cross sectional area, immediately after and up to 24 hours post exercise depending on the amount of inflammatory agents present in the muscle. This enlargement of the muscle suggests that inflammatory agents are present in the muscle and that it is not able to function correctly. However, it is still unclear how the
infraspinatus responds to pitching, or how long it takes to recover. Furthermore, no studies have investigated the effects of recovery methods to return infraspinatus size to baseline levels.

**Range of Motion (ROM)**

The most commonly recognized adaptation in pitchers is a reduced amount of internal rotation, with a concomitant increase in external rotation in the dominant arm compared to the non-dominant arm. The reason for this adaptation may be due to several causes: the development of posterior capsule thickness, increased posterior shoulder tightness, humeral retrotorsion and increased anterior laxity.

Tightness of the posterior shoulder has been previously associated with reduced shoulder range of motion. During a normal bout of pitching, the shoulder external rotators, latissimus dorsi, rhomboids, and middle upper trapezius are subject to chronic eccentric overload. When tensile strain is placed on the musculature, separation of the sarcomere occurs. This damage allows the release of intramuscular calcium, which facilitates fibril contraction and brings about muscular shortening somewhere between 4 to 18 hours after throwing, and may produce delayed onset muscle soreness 24-48 hours after throwing. The tensile strain may be exacerbated by the architecture of the rotator cuff muscles, whose pennation angles hinder their ability to withstand lengthening forces. Since the rotator cuff’s fibers are consistently short in length this suggest rotator cuff muscles (particularly the supraspinatus) are highly sensitive to length change. This inability to withstand eccentric loads causes adaptation to the posterior structures of the shoulder leading to pitchers losing passive internal rotation in the dominant shoulder both after a single bout of pitching. This ROM loss appears to be clinically significant, as
Reinhold et al observed a 9 degree internal rotation ROM deficit (GIRD) 30 minutes after professional pitchers threw 50-60 pitches off a mound. However, it is not known at which day after throwing the shortening returns to normative values.

Humeral retrotorsion and/or anterior capsular laxity may also explain some of the increase external rotation and decrease in internal rotation that pitchers experience over their careers. Theoretically, the excessive external rotation brought about during the late-cocking phase of throwing creates an anterior slide of the humerus in the glenoid. This slide creates “micro-trauma” to the anterior capsule, which is then thought to stretch the capsuloligamentous complex over time. Due to this laxity, force is distributed to the posterior capsule causing it to undergo damage and become taut. Humeral retrotorsion, or the bony twist about the long axis of the humerus, also plays a role in perceived anterior laxity and posterior capsule thickening. The posterior twist of the proximal humerus thought to be caused by excessive overhead activity at a young age allows the shoulder for more external motion while decreasing the available internal range of motion. While the measurement of humeral retrotorsion and posterior capsule thickness are important, many clinicians still cannot perform these measurements because of inaccessibility to musculoskeletal ultrasound. Therefore, the measurement of internal and external rotation is still warranted.

The deficits in internal rotation ROM in pitchers over their careers can have an effect on injury rates. Players who present with total range of motion deficits (TROM) of as little as 5-8 degrees or internal rotation deficits of 18-25 degrees on their dominant arms compared bilaterally are more likely to become injured than athletes without ROM deficits. As stated previously, pitchers experience an acute loss of approximately 9
degrees of internal rotation after a start, so if range of motion is only partially recovered, they likely increase injury risk over time.

**Neuromuscular Fatigue**

The repetitive eccentric muscle contraction that pitching requires may also be a reason for injuries in baseball athletes. Muscular fatigue affects the ability of the myofibrils to activate and function as it would normally. Lattier et al. have proposed that the accumulation of hydrogen ions and inorganic phosphate creates a central fatigue effect; which is defined as the decrease in muscle force attributable to a decline in motorneuronal output.\(^{12}\) As this output decreases, failure of excitation-contraction coupling then plays a role in the decreased isometric strength of the musculature.\(^{14}\) In addition, Semmler et al.\(^{85}\) proposed that eccentric exercise results in substantial decrease in motor unit recruitment thresholds, discharge rates, motor unit conduction velocities and synchronization.\(^{85}\) These inhibitions could lead to voluntary activation deficits of the musculature and subsequent injury when an athlete enters a fatigue state. However, it remains unclear how long these effects last in pitchers, or what can be done to recover from them.

When examining pitching induced-fatigue, a common site of muscle inhibition is the rotator cuff. At the end of an intense throwing session, pitchers experience a loss in external rotation strength and slower pitch velocity.\(^{9,16}\) The decrease in strength appears to be a result of infraspinatus inhibition, as its voluntary activation is reduced by 46%.\(^{15}\) Because of decreased infraspinatus inhibition, velocity and pitching biomechanics may be altered to protect the upper extremity from excessive forces and subsequent injury. As a pitcher approaches later innings in the game, the trunk becomes oriented more
vertically while shoulder and knee range of motion decreases during throwing.\(^9\) These decreases in maximal shoulder external range of motion and knee angle at ball release has been shown to decrease pitching velocity by 5 miles per hour.\(^{20}\) However, these effects do not appear to last, as 12 minor league pitchers actually experienced an increase in fastball velocity over an 8 game span, with no differences in days rest or work to rest ratio.\(^{46}\) This result may be due to either a small sample size, between-game treatment from their Athletic Trainer, or some other type of unmeasured compensatory mechanism. Furthermore, in-game velocity may not be an accurate measure of recovery, since pitchers may naturally return velocity back to baseline in a 5 day span. Furthermore, it has not been determined whether fatigue may still be present on days in which the athletes are not pitching in a game. If the athletes are still fatigued mid-week, pitching biomechanics may suffer and excessive stress and microtrauma may arise during bullpen sessions, potentially leading to chronic injury.

**Arm-Care**

Clinicians are able to apply their knowledge of adaptations to pitching when treating a baseball player. In using this knowledge, clinicians are able to develop preventative programs for pitchers to follow that will help minimize the risk of injury during a baseball season. These programs may include shoulder and forearm exercises to increase strength or range of motion, thoracic spine mobility and/or hip mobility. Most starting pitchers require 5 to 7 days, to recover before their next start, depending on competition level and energy expenditure. At the professional level starting pitchers make an appearance every 5 days compared to every 7 days at the collegiate level.\(^ {42,86,87}\) This discrepancy may be due to the rule that all athletes in the NCAA are required 1 day of

43
complete rest from activity. In this 5-7 day time frame, strength, range of motion, velocity and neuromuscular fatigue should return to normal levels.

Returning these measurements to baseline provides a quantitative definition of when a player has recovered from maladaptations associated with pitching. Recovery has been discussed in previous literature as a 2-stage process. During the first stage, the body returns what was lost, i.e., fatigue; While the second stage requires adaptation or super compensation to training demands. Simply returning to a nonfatigued state likely does not represent a complete recovery because the body reacts to the demands placed upon it. Therefore, continuous adaptation is taking place, and the body needs to exceed baseline levels of strength and range of motion to minimize injury risk. Athletes also continuously attempt to enhance performance and efficiency, which creates the need to reach a higher level of fitness for true recovery. This definition of recovery requires clinicians to institute “arm-care” programs for their athletes to produce levels of fitness that can prevent injury in elite athletes. These arm-care programs encompass all aspects of keeping a pitcher healthy through a season, such as checking range of motion periodically, increasing the strength of important musculature, decreasing soreness and increasing mobility through the use of various modalities. It is the goal of the programs to maintain these healthy properties in order to protect the ability of surrounding tissue to effectively allow movement in the throwing shoulder, or joint stability.

Traditional Treatment of Pitchers

Ice

One current standard of care for a pitcher is to apply ice to the shoulder. Physiologically, cryotherapy produces an analgesic affect by numbing the skin and
constricts the blood vessels, thus decreasing inflammatory agents. However, ice may not reach deep enough to proved true effects, as shown by the conflicting evidence on cryotherapy in the reduction of soreness. A meta-analysis has found that using ice after exercise-induced muscular soreness was more beneficial for reducing delayed onset muscle soreness than not using any recovery modality, but the risk of bias limits the application of the results. The same study also showed no clinically significant results comparing ice water immersion to active recovery, compression, contrast or multiple uses of cold-water immersion treatments. Similarly, some literature suggests that cryotherapy does not effect the recovery of musculature after eccentric exercise. Based on the conflicting literature and quality of studies, the effect cryotherapy post-pitching may not be an appropriate standard of care because it does not definitively provide enhancement to recovery. Therefore, other modalities may be needed to ensure proper healing.

**Stretching**

Besides ice, stretching is the other technique most frequently used to alleviate soreness and improve sports performance. It has almost become commonplace for an active person to stretch before and/or after an event to aid in recovery and prevent injury, even though scientifically evidence is lacking on its effects. In practice, light exercise followed by pain-free stretching appears to be more effective in reducing DOMS than a day of complete, physical rest. Since the posterior musculature undergoes damage with subsequent fibril contraction and thixotrophy stretching could theoretically decrease these alteration. This stretching intervention may succeed by lengthening the muscular tissue that is in a thixotropic state after pitching activity. Because the posterior
musculature theoretically becomes shortened as a result of pitching, stretching within the thixotropic state could allow those muscles to be lengthened, which may help return glenohumeral internal rotation (IR) and horizontal adduction (HA).

However, the theory of stretching causing muscle lengthening has been refuted by Ben et al., who found that no increase in muscle extensibility occurred after thirty minutes of sustained hamstring stretching per day for 6 weeks. In addition to this study, Harvey et al. found 4 weeks of 30 minutes of stretching per day did not produce a significant increase in ankle mobility in recently injured patients with spinal cord injuries (SCI). This body of literature provides some evidence that an increase in ROM as a result of a stretching program may be primarily neural in nature as opposed to mechanical. Therefore, the stretching program may not actually be able to lengthen tissue in the rotator cuff or reduce adhesions, as previously theorized. However, despite the mechanism, an increase in ROM appears to be a beneficial adaptation as long as muscle strength and activation rates remain similar.

**Non-Traditional Treatment of Pitchers**

**Throwing**

Throwing the day after a start is another method used in the reduction of post-pitching symptoms. Alan Jaeger, of the J-bands, wrote an article that proposes a throwing program for pitchers throwing on a 7-day routine. Based on this program, a pitcher should throw lightly the day after an intense pitching bout, working themselves to a distance of 90-120 feet or as far as up to 150-200 feet if few pitches were thrown throughout the game. The term “stretch throwing” is used to describe this method, and
increased blood flow throughout recovery is the goal.\textsuperscript{98} While this theory may have benefits for pitchers, the activity of stretching-out the arm or long-tossing may actually be harmful because long throwing distances with higher ball height than normal increases torque in the elbow and shoulder\textsuperscript{99}. Because the creators of this “stretch throwing” program have financial interest in their product, no high quality studies have examined its effects scientifically or determined the potential harm for a pitcher. Therefore, more literature is needed to compare light throwing to passive stretching and shoulder exercises.

**Active Recovery/Strengthening**

The last method clinicians have started to use recently to reduce soreness and pain after pitching is active recovery. The pitching community typically uses a long run on the day after a start as treatment for arm soreness in the collegiate and high school setting.\textsuperscript{42} This run is mainly meant to be 30-45 minutes in length and to aid in recovery through increased blood flow. Theoretically, running will increase the number of white blood cells and antibodies that help clear unwanted metabolites that are present in the shoulder and elbow in pitchers because it is an area that has just undergone microtrauma.\textsuperscript{87} Through metabolite clearing, a relaxation effect is created which in turn relieves pain, tenderness, and reduces muscle hypertonicity.\textsuperscript{87}

Most of these studies on active recovery have examined participants after riding a bike, using an upper body ergometer (UBE), or running at different intensities. After a heavy isometric quadriceps workout on a dynamometer light, active exercise, cycle ergometer (10 W) at 60 rpm for 5 minutes immediately after exercise, was shown to promote better recovery than rest alone.\textsuperscript{44} Andersen et al. also found that that light, active exercise produced relief in
DOMS after eccentric weight training for the upper trapezius, based on a numerical rating scale, and pressure pain threshold. These results differed from others, which found that light, active exercise after a heavy eccentric routine did not provide any benefit compared with massage or microcurrent electrical stimulation. Although little information is available at the shoulder, a study comparing the effects of various therapeutic measures on shoulder strength and muscle soreness after pitchers threw a 7-inning game suggested that ice and UBE exercise was the optimal treatment when compared to ice, exercise or rest alone. However, the use of a UBE is not prevalent in many high schools, colleges, or other training facilities, so athletes may not be able to complete this training regime. Long-term use of a UBE will likely not increase strength or ROM to create super compensation to training demands that are needed by pitchers at an elite level. Therefore, information on other, more widely used, other recovery methods is needed to determine their effects on recovery.

Active recovery programs for baseball pitchers that include strengthening vary between sports medicine professionals. For instance, one organization uses 3-different workouts per pitching week with a focus on scapular strength one day, a taxing rotator cuff workout mid-week, and a lighter neuromuscular control day closer to their next pitching outing. Another professional organization uses one complete rotator cuff program three times per week, and a third organization completes a scapular-centered exercise program the day after a start and two rotator cuff workouts the following days. In each of these organizations, the same four principles are followed. The goal is to maintain range of motion, strengthen the muscles surrounding the glenohumeral and scapulothoracic joints, emphasize dynamic stability and neuromuscular control, and
increase core and lower body function.\textsuperscript{102} Pitching seems produce a more protracted scapula on the dominant arm,\textsuperscript{51} so exercises are designed to pull the scapula back into retraction. These goals are attained through the help of skilled athletic trainer, physical therapist, coaching staff, and team physicians whom know the adaptations from pitching. However, the treatments for these adaptations are anecdotal. There is an underlying need for scientific evidence examining how these active recovery programs, which target shoulder strength, truly affect range of motion, strength and soreness in a pitcher.

**Conclusion**

Our study will be the first to compare scapular-specific exercises to both throwing and stretching in an attempt to reduce the adaptations that are present post-pitching. Preventing injury is a primary concern of sports medicine professionals. At lower levels of competition, many baseball players do not have the luxury of having an athletic trainer or strength and conditioning coach on site to supervise and provide feedback. Even at the professional level organizations use different exercises and routines based on anecdotal rather than quantitative evidence. Therefore, it is difficult to identify which programs are most effective, especially when yearly injury rates are inconsistent. Furthermore, current literature does not provide evidence as to what recovery methods are best to reduce an athlete’s soreness or return their performance to baseline levels. The overall aim of this study is to develop general exercise recommendations that can allow future research on the best methods to alleviate the acute effects from pitching during the course of a week.
References

1. ESPN. MLB Player Pitching Stats - 2015.


24. Oyama S, Myers JB, Blackburn JT, Colman EC. Changes in infraspinatus cross-


30. Thomas SJ, Swanik K a, Swanik C, Huxel KC, Kelly JD. Change in glenohumeral rotation and scapular position after competitive high school baseball. *J Sport


37. Harshbarger ND, Eppelheimer BL, Mcleod TCV, Mccarty CW. The Effectiveness of Shoulder Stretching and Joint Mobilizations on Posterior Shoulder Tightness. *J


42. Coach P. Division 1 Pitching Coach. 2015:n/a.

43. Kentta G, Hassmen P. Overtraining and recovery: a conceptual model


Duggan JP, Osadebe UC, Alexander JW, Noble PC, Lintner DM. The impact of ulnar collateral ligament tear and reconstruction on contact pressures in the lateral


75. Mihata T, Gates J, McGarry MH, Neo M, Lee TQ. Effect of posterior shoulder tightness on internal impingement in a cadaveric model of throwing. *Knee*


83. Sabick MB, Kim Y-K, Torry MR, Keirns Ma, Hawkins RJ. Biomechanics of the shoulder in youth baseball pitchers: implications for the development of proximal

84. Yamamoto N, Itoi E, Minagawa H, et al. Why is the humeral retroversion of
throwing athletes greater in dominant shoulders than in nondominant shoulders? *J

85. Semmler JG. Motor unit activity after eccentric exercise and muscle damage in

86. Szymanski DJ. Collegiate Baseball In-Season Training. *Strength Cond J.*

87. Szymanski DJ. Physiology of Baseball Pitching Dictates Specific Exercise
doi:10.1519/SSC.0b013e31819d34de.


Stretching: Acute and Chronic? The Potential Consequences. *Strength Cond J.*


From Eccentric-Induced Muscle Damage. *J Strength Cond Res.* 2013;27(5):1354-


APPENDIX B

TABLES AND FIGURES

B.1 Stretching Routine Figures

Figure B.1.a Shoulder Flexion Stretch
Figure B.1.b Pectoralis Minor Stretch
Figure B.1.c Horizontal Adduction Stretch
Figure B.1.d Posterior Shoulder Stretch
Figure B.1.e Internal Rotation Stretch
Figure B.1.f Sleeper Stretches (high/mid/low)
B.2 Strengthening Routine Figures

Figure B.2.a Table top Protraction/Retraction to the front
Figure B.2.b Table Top Protraction/Retraction to the side
Figure B.2.c Blackburn T-Holds and A-Holds
Figure B.2.d Blackburn Y-Holds and 90/90-Holds
Figure B.2.e Thumbtacks
Figure B.2.f Low row plus External Rotation
Figure B.2.g Ultrasound Technique

Fig. 1. Standardized location for the measurement of the infraspinatus CSA, and placement of the custom-made template over the muscle. Right: standardized location for the measurement of the infraspinatus CSA. Left: placement of the custom-made template over the infraspinatus muscle.
B.3  Strength Measurement Figures

Figure B.3.a Shoulder Flexion
Figure B.3.b Shoulder Abduction
Figure B.3.c Shoulder Adduction
Figure B.3.d Shoulder Extension
Figure B.3.e Shoulder Scaption
Figure B.3.f Shoulder External Rotation
Figure B.3.g Shoulder Internal Rotation
B.4 Range of Motion Testing Figures and Tables

Figure B.4.a Shoulder IR ROM
Figure B.4.b Shoulder ER ROM
B.5 Tables

Table B.5.a: Combined Flexion Strength across groups

![Bar chart showing combined flexion strength across baseline, day 2, and day 4.](chart.png)
**Table B.5.b: Combined extension strength across groups**

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Day 2</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pounds (lbs)</td>
<td>33</td>
<td>35</td>
<td>37</td>
</tr>
</tbody>
</table>

* Day 4 significantly greater than baseline (p<.05)
Table B.5.c: Combined Scaption Strength across groups

<table>
<thead>
<tr>
<th></th>
<th>Pounds (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>35</td>
</tr>
<tr>
<td>Day 2</td>
<td>36</td>
</tr>
<tr>
<td>Day 4</td>
<td>39</td>
</tr>
</tbody>
</table>

![Scaption Strength](image)
Table B.5.d: Combined Adduction Strength across groups

* Day 4 significantly greater than baseline (p<.05)
Table B.5.e: Combined Abduction Strength across groups

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Day 2</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pounds (lbs) Abduction Strength</td>
<td>32</td>
<td>35</td>
<td>36</td>
</tr>
</tbody>
</table>
Table B.5.f: Combined Internal Rotation Strength across groups

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Day 2</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength (lbs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>38</td>
<td>42</td>
</tr>
</tbody>
</table>
Table B.5.g: Combined External Rotation Strength across groups

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Day 2</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pounds (lbs)</td>
<td>36</td>
<td>37</td>
<td>38</td>
</tr>
<tr>
<td>External Strength</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Bar chart showing external strength across baseline, day 2, and day 4]
Table B.5.h: Combined External Rotation ROM across groups

![Combined External Rotation ROM across groups graph](image)

- **Baseline**
- **Day 2**
- **Day 4**

External ROM
Table B.5.i: Internal Rotation ROM across groups

* Day 2 significantly less than baseline (p<.05)
Table B.5.j: Combined Infraspinatus CSA across groups
APPENDIX C

IRB DOCUMENT

DATE: September 1, 2015

TO: Nick Jensen
FROM: University of Delaware IRB

STUDY TITLE: [791811-1] Comparison of Three Different Post-Pitching Recovery Methods

SUBMISSION TYPE: New Project

ACTION: APPROVED

APPROVAL DATE: September 1, 2015

EXPIRATION DATE: August 31, 2016

REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # 4

Thank you for your submission of New Project materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.
Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Maria Palazuelos at (302) 831-8619 or mariapj@udel.edu. Please include your study title and reference number in all correspondence with this office.
APPENDIX D

IRB CONSENT FORM

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

Title of Project: Comparison of Three Different Post-Pitching Recovery Methods

Principal Investigator(s): Nicholas Jensen.

You are being invited to participate in a research study. This consent form tells you about the study including its purpose, what you will be asked to do if you decide to take part, and the risks and benefits of being in the study. Please read the information below and ask us any questions you may have before you decide whether or not you agree to participate.

WHAT IS THE PURPOSE OF THIS STUDY?

The purpose of this study is to compare three different post-pitching recovery methods. The goal is to see which method provides a better relief of symptoms after a bout of pitching in order to further direct the care for a pitcher’s arm.

You will be one of approximately 30 participants in this study. You are being asked to participate because you are a competitive baseball pitcher at the collegiate varsity, high school varsity, or collegiate club level. You should not participate if you currently have an injury that does not allow you to pitch competitively in a game.

WHAT WILL YOU BE ASKED TO DO?

This study will take place at the University of Delaware, Student Health and/or STAR Campus. As part of this study you will be asked to fill out a questionnaire, take a baseline measurement of shoulder strength, shoulder range of motion, pitching velocity, and also take a baseline pictures of your infraspinatus and supraspinatus (shoulder muscles), which should take roughly 15 minutes. Once these are measured, you will complete your normal pitching activities during a practice or game, which only ice will be given if requested until the following day. You will then be retested the next day for strength, range of motion, self-reported symptoms and an images of your shoulder muscles will be taken again. After the 2nd test, you will complete either a day of rest with ice, a day of shoulder exercises and ice or a day of light throwing and ice.

Throughout the study, you will complete each of these protocols once with at least one week in between testing. All these measurements plus velocity will also be taken again on the fourth day. Your participation in this study will involve up to 3 visits the first week, which may take around 45 minutes, and 2 visits each consecutive week for 2 weeks, totaling about 30 minutes.

Shoulder Strength

To assess shoulder strength a handheld dynamometer will be used for isometric strength of the shoulder musculature. The motions that will be tested are; shoulder internal rotation, measured while sitting with
your arm behind your back and pushing back as hard as you can, shoulder external rotation, measured while you are on your side and scaption, measured with your thumb up and your arm at 30 degrees in the scapular plane.

Glenohumeral Internal and External Range of Motion

To assess shoulder range of motion two clinicians will be used. You will be on your back while one clinician rotates your arm forward and backward while stabilizing your shoulder. The other clinician uses a measuring device (goniometer) to measure the degrees traveled in each direction. You will have your right arm tested first and they will be taken 3 times to make sure we are accurate.

Pitching Velocity

To measure pitching velocity you will warm-up and begin the allotted bullpen instructions from your coach. 5 Fastballs will be measured using a radar gun and the top velocity reached will be used. Pitching velocity will be measured prior to the study and again on the 4th day after the pitching bout.

Infraspinatus Cross-Sectional Area

To measure the size of one of your shoulder muscles, the researcher will use an ultrasound machine, which allows us to see your muscles and take pictures of them. You will be asked to remove your shirt to allow the researcher access to the back of your shoulder. The researcher will also use a marker to mark a couple sports on your shoulder to make sure the right spot is measured.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

Possible risks of participating in this research study include an increased risk of soreness from strengthening or from the introduction of throwing on a normal day off. With the increased exposure to throwing, injury may occur, but the chances are extremely low since you will be throwing at a self-monitored intensity. An athletic trainer will be present to ensure proper form on strengthening exercises to minimize injury. You will also be observed while you throw to ensure you are throwing at a comfortable intensity. Applying ice to the shoulder may cause a numbing and weak effect to the area. Icing for longer than the allotted 20 minutes may cause adverse effects and decrease recovery to the area. No other risks are foreseen other than those that you are already exposed to throughout daily life.

WHAT ARE THE POTENTIAL BENEFITS?

You will be able to identify which method you feel produces the best form recovery, and scientific measurements will be provided to enhance your decision-making ability. The knowledge gained from this study may further direct the care for pitchers.
NEW INFORMATION THAT COULD AFFECT YOUR PARTICIPATION:

During the course of this study we may learn new information that could be important to you. This may include information that could cause you to change your mind about participating in the study. We will notify you as soon as possible if any new information becomes available.

HOW WILL CONFIDENTIALITY BE MAINTAINED? WHO MAY KNOW THAT YOU PARTICIPATED IN THIS RESEARCH?

Each participant will be assigned a subject number. The list matching personal identification information and subject number will be held on a computer file that is encrypted and password protected. Only the primary investigator will have access to this file, and all personal identifiers will be destroyed after completion of the study. All data stored on paper will be stored in a locked cabinet for three years, after which it will be destroyed. While the results of this research may be published and presented at conferences, subjects name or identity will not be revealed. Your research records may be viewed by the University of Delaware Institutional Review Board, but the confidentiality of your records will be protected to the extent permitted by law.

The confidentiality of your records will be protected to the extent permitted by law. Your research records may be viewed by the University of Delaware Institutional Review Board, which is a committee formally designated to approve, monitor, and review biomedical and behavioral research involving humans. Records relating to this research will be kept for at least three years after the research study has been completed.

USE OF DATA COLLECTED FROM YOU IN FUTURE RESEARCH:

The research data we will be collecting from you during your participation in this study may be useful in other research studies in the future. Your choice about future use of your data will have no impact on your participation in this research study. Do we have your permission to use in future studies data collected from you? Please write your initials next to your preferred choice.

________ YES __________ NO

WILL THERE BE ANY COSTS TO YOU FOR PARTICIPATING IN THIS RESEARCH?

There will be no costs associated with participating in the research study.

WILL YOU RECEIVE ANY COMPENSATION FOR PARTICIPATION?

There will be no compensation for participating in this study.

DO YOU HAVE TO TAKE PART IN THIS STUDY?
Taking part in this research study is entirely voluntary. You do not have to participate in this research. If you choose to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part in the research at a later date, there will be no penalty or loss of benefits to which you are otherwise entitled. Your decision to stop participation, or not to participate, will not influence current or future relationships with the University of Delaware.

If, at any time, you decide to end your participation in this research study, please inform our research team by telling the investigator(s) by calling Nicholas Jensen at (908) 246-1022 or via email njensen@udel.edu.

WHO SHOULD YOU CALL IF YOU HAVE QUESTIONS OR CONCERNS?

If you have any questions about this study, please contact the Principal Investigator, Nicholas Jensen, at (908) 246-1022 or njensen@udel.edu.

You may also contact Dr. Swank via email at cswank@udel.edu.

If you have any questions or concerns about your rights as a research participant, you may contact the University of Delaware Institutional Review Board at irb-research@udel.edu or (302) 831-2137.

Your signature on this form means that: 1) you are at least 18 years old; 2) you have read and understand the information given in this form; 3) you have asked any questions you have about the research and the questions have been answered to your satisfaction; and 4) you accept the terms in the form and volunteer to participate in the study. You will be given a copy of this form to keep.

Printed Name of Participant

Signature of Participant

Date

Person Obtaining Consent

Person Obtaining Consent

Date

Participant’s Initials ___________________
APPENDIX E

IRB PROTOCOL

HUMAN SUBJECTS PROTOCOL
University of Delaware

Protocol Title: Comparison of three different types of post-pitching recovery methods

Principal Investigator: Nicholas D. Jensen
Name: Nick Jensen
Department/Center: Athletics
Contact Phone Number: 908.246.1022
Email Address: njensen@udel.edu

Advisor (if student PI): Dr. Swanik
Name: Charles "Buz" Swanik
Contact Phone Number: 856.266.7221
Email Address: cswanik@udel.edu

Other Investigators: Aaron Struminger

Investigator Assurance:
By submitting this protocol, I acknowledge that this project will be conducted in strict accordance with the procedures described. I will not make any modifications to this protocol without prior approval by the IRB. Should any unanticipated problems involving risk to subjects occur during this project, including breaches of guaranteed confidentiality or departures from any procedures specified in approved study documents, I will report such events to the Chair, Institutional Review Board immediately.

1. Is this project externally funded? □ YES ☑ NO
If so, please list the funding source:

2. Research Site(s)
☑ University of Delaware
□ Other (please list external study sites)

Is UD the study lead? ☑ YES □ NO (If no, list the institution that is serving as the study lead)
3. Project Staff
Please list all personnel, including students, who will be working with human subjects on this protocol (insert additional rows as needed):

<table>
<thead>
<tr>
<th>NAME</th>
<th>ROLE</th>
<th>HS TRAINING COMPLETE?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicholas Jensen</td>
<td>Lead Investigator</td>
<td>yes</td>
</tr>
<tr>
<td>Charles Swank</td>
<td>Advisor</td>
<td>yes</td>
</tr>
<tr>
<td>Aaron Struminger</td>
<td>Investigator</td>
<td>yes</td>
</tr>
</tbody>
</table>

4. Special Populations
Does this project involve any of the following:

Research on Children? Yes
Research with Prisoners? No

If yes, complete the Prisoners in Research Form and upload to IRBNet as supporting documentation
Research with Pregnant Women? No
Research with any other vulnerable population (e.g. cognitively impaired, economically disadvantaged, etc.)? please describe No

5. RESEARCH ABSTRACT  Please provide a brief description in LAY language (understandable to an 8th grade student) of the aims of this project.

The purpose of this study is to compare three different post-pitching recovery methods in order to reduce arm injuries in pitchers. Each baseball team typically develops its own program that consists of different exercises that are aimed at increasing shoulder strength and flexibility while reducing soreness. These exercises are also performed at different times during the week, as each team’s coaches and athletic trainers have different ideas about the best point in the recovery process to introduce specific shoulder strengthening exercises to produce the best results.

This study will test 3 different exercise routines on the day after pitchers throw in a game. This time frame was chosen because it is generally the time where pitchers are most sore and lack the most range of motion. The 3 interventions used will be light shoulder strengthening with ice, light throwing with ice, and stretching with ice. These exercises are typically used to promote blood flow and movement, but it remains unclear which is best. Each will be performed after 3 separate throwing sessions, and all three routines have the goal of reducing post-pitching symptoms and promoting recovery. To assess recovery, range of motion, pitching velocity, strength, self-reported function and ultrasound measures will be used.
6. PROCEDURES Describe all procedures involving human subjects for this protocol. Include copies of all surveys and research measures.

As part of this study each subject will be asked to fill out a questionnaire, and a baseline measurement of shoulder strength, shoulder range of motion, pitching velocity, and ultrasound images of the infraspinatus and supraspinatus (rotator cuff muscles) will be taken. This protocol should take about 15 minutes per session. Once these are measured, the subject will complete your normal pitching activities during a practice or game. After pitching, only ice will be given if requested until the next day. The next day the subject will be retested for strength, range of motion, self-reported symptoms, and cross-sectional area of rotator cuff muscles. Following the second testing protocol, each pitcher will complete either a period of rest and stretch only, which will take 25 minutes, shoulder exercises which will take 25 minutes, or light throwing, which will take 30 minutes. Ice will be added to all protocols to help with soreness and inflammation. Throughout the study, each subject will complete each of these protocols once with at least one week in between testing. All these measurements taken the day after pitching, with the addition of pitching velocity will also be taken again on the fourth day following the normal pitching activity. Participation in this study will involve 3 visits the first week, which will take around 45 minutes, and 2 visits for the other 2 testing weeks, totaling about 30 minutes per week. All subjects will only have their dominant arms tested, and each measurement will be taken 3 times for reliability.

Shoulder Strength
To assess shoulder strength a handheld dynamometer will be used for isometric strength of the shoulder musculature. The motions that will be tested are; shoulder internal and external strength as well as shoulder scaption. To test the subscapularis (internal rotation) the subject will be sitting with their throwing hand on the small of the back with palm faced away from the back. The subject will then push against a hand-held dynamometer (Nicholas MMT), which will record the strength measurement. To measure the infraspinatus (external rotator) the subject will be in a sidelying position with the humerus at 0 degrees of abduction with the forearm at 90 degrees of flexion in the external rotation position. To test the supraspinatus, the subject will be sitting with their humerus elevated to 90 degrees at a 30 degree angle forward from the horizontal plane of the body and the thumb up. Then the subject will try to raise their arm along that plane against the resistance of the handheld dynamometer.

Glenohumeral Internal and External Range of Motion
To assess shoulder range of motion two clinicians will be used. The subject will be on his back with the humerus abducted to 90 degrees and the elbow flexed to 90 degrees. One clinician will stabilize the scapula and move the limb into both maximal external and internal ranges of motion, while the other clinician uses a digital inclinometer to measure the degrees traveled. All subjects will have their right arm tested first and each measurement will be taken 3 times for reliability.

Pitching Velocity
To measure pitching velocity, each subject will warm-up and begin their allotted bullpen instructions from their coach. 5 Fastballs will be measured using a radar gun and the top velocity
reached will be used. Pitching velocity will be measured prior to the study and again on the 4th day after the pitching bout.

**Infraspinatus Cross-Sectional Area Supraspinatus Cross-Sectional Area**
Measuring each subject’s cross-sectional area of their infraspinatus will be completed using a diagnostic ultrasound. The superior-medial border of the scapula will be marked, as well as the acromion and the inferior angle of the scapula. A line will be drawn from the superior-medial border perpendicular to the other two marks. The ultrasound probe will be placed and dragged along this line. Software on the ultrasound unit will allow the image to expand as the ultrasound head is dragged along the skin. Following the collection process, the image will be saved, exported to an encrypted hard drive, and evaluated by Image J software (National Institute of Health, Bethesda, MD).

**Supraspinatus Thickness**
Thickness of the supraspinatus will begin with the subject seated. The investigators will palpate the spine of the scapula and place the ultrasound head parallel to this structure. The ultrasound head will be moved until the “supraspinatus triangle” is visible on the screen. The digital calipers on the screen will then measure 2cm from the “supraspinatus triangle” following the connective external fascia. Then, the calipers on the ultrasound unit will take a cross-sectional measurement of the supraspinatus from that point.

7. **STUDY POPULATION AND RECRUITMENT**
Describe who and how many subjects will be invited to participate. Include age, gender and other pertinent information.

15-30 Division 1 Collegiate/Club/High School male baseball players between the ages of 16-24 that have been pitching competitively over a year. The Primary Investigator will approach the University of Delaware Baseball Team and Club Baseball team. If more subjects are needed then the BBA Academy in Delaware will be approached. The coaches of each team will be approached by the PI and informed of participating in the study and that have the choice for their players to not participate. It will be up to the PI to approach and obtain recruitment/consent for the study. Coaches will have very limited responsibility in the study.

Describe what exclusionary criteria, if any will be applied.

Any current injury that prevents an athlete from pitching at a competitive level.

Describe what (if any) conditions will result in PI termination of subject participation.

Subject participation could be terminated by investigators if unanticipated events are deemed a health risk beyond those which are described in the protocol, or the participant is not cooperating with the study procedures or instructions that are specified in the consent form.

8. **RISKS AND BENEFITS**
List all potential physical, psychological, social, financial or legal risks to subjects (risks listed here should be included on the consent form).
Soreness and/or injury may result from pitching activity. However, the pitchers willingly accept this risk from participating in sport, so the pitching procedures used in this study do not increase risk of injury. Resistance training and long-toss throwing may slightly increase risk of injury or muscle strain, but these procedures are commonly used by pitchers at these competitive levels. Applying ice to the shoulder may cause a numbing and weak effect to the area. Icing for longer than the allotted 20 minutes may cause adverse effects and decrease recovery to the area.

In your opinion, are risks listed above minimal* or more than minimal? If more than minimal, please justify why risks are reasonable in relation to anticipated direct or future benefits.

(*Minimal risk means the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests)

The risks above are minimal and highly unlikely. The athletes will not be performing any activity that is new or uncommon.

What steps will be taken to minimize risks?

1. Attention to proper form will be taken while athlete completes exercises.
2. Throwing will be symptom-based. Athletes will be told to throw light and comfortably to a distance that does not produce arm pain.
3. Subjects will be encouraged to tell the investigators of discomfort with any testing measures.
4. A certified athletic trainer will be monitoring all activity.

Describe any potential direct benefits to participants.

Participants will be able to determine which method of care that feels best for them individually.

Describe any potential future benefits to this class of participants, others, or society.

The study may be a stepping-stone to further studies in providing recovery methods for pitchers. The direction of pitching arm care may be changed upon evidence from this study by providing evidence as to which programs are best.

If there is a Data Monitoring Committee (DMC) in place for this project, please describe when and how often it meets.

9. COMPENSATION
Will participants be compensated for participation?

No.
If so, please include details.

10. DATA
Will subjects be anonymous to the researcher?

Subjects will not be anonymous.

If subjects are identifiable, will their identities be kept confidential? (If yes, please specify how)

Yes, the researchers will keep a code list matching code to subject identity on computer file. The subject number will be kept on the paper copies, but not their names. The subject number will be on all data sheets used for testing. Information from each subject will not be shared with anyone not involved in the study.

How will data be stored and kept secure (specify data storage plans for both paper and electronic files. For guidance see http://www.udel.edu/research/preparing/datasetorage.html)

Paper files will be kept in a locked file cabinet on campus for 3 years and any electronic files will be stored in a password protected file on a University Approved computer that has regular and secure back-ups.

How long will data be stored?

In accordance to 45 CFR 46.115(b) the data will be kept for up to 3 years after completion of the project.

Will data be destroyed? ☑ YES ☐ NO (If yes, please specify how the data will be destroyed)

After 3 years, all paper documents will be shredded. All electronic files will archived but stripped of any subject identifiers.

Will the data be shared with anyone outside of the research team? ☑ YES ☐ NO (If yes, please list the person(s), organization(s) and/or institution(s) and specify plans for secure data transfer)

How will data be analyzed and reported?
Data will be analyzed through SPSS with repeated-measures ANOVAs.

11. CONFIDENTIALITY
Will participants be audiotaped, photographed or videotaped during this study?
Only ultrasound images of the infraspinatus and supraspinatus will be used in the study. No pictures that could identify a subject will be used.

How will subject identity be protected?
Each subject will be assigned a number and only the primary investigator will maintain the records for each subject.

Is there a Certificate of Confidentiality in place for this project? (If so, please provide a copy).
## APPENDIX F

**WEEKLY MEASUREMENT SHEET**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>