

COMPARISON OF THE EFFECTS OF TWO RECOVERY METHODS
AFTER COLLEGIATE BASEBALL PITCHING

by

Hiroto Kawamura, B.S.

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Committee Members:

Rod A. Harter, Chair

Luzita I. Vela

Kevin McCurdy

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LIST OF ABBREVIATIONS

Abbreviation	Description
DOMS	Delayed onset muscle soreness
GIRD	Glenohumeral internal rotation deficit
LSC	Light shoulder exercise, stretching and cryotherapy treatment group
PROM	Passive range of motion
ROM	Range of motion
SC	Stretching and cryotherapy treatment group
SLAP	Superior labrum anterior and posterior
VAS	Visual analog scale

ABSTRACT

Context: The localized muscular fatigue, acute loss of glenohumeral strength and passive range of motion (PROM), and delayed onset muscle soreness (DOMS) that intercollegiate and professional baseball pitchers experience following a game must be minimized or eliminated before they can safely pitch in their next outing. The combination of light shoulder exercise, stretching, and cryotherapy is commonly used after baseball pitching as the recovery method to hasten the restoration of shoulder muscular strength and PROM, and reduce the symptoms of DOMS. However, the effectiveness of the light shoulder exercise program for recovery after baseball pitching remains unclear. **Objective:** To compare the effectiveness of two recovery methods, stretch and cryotherapy (SC), and a light shoulder exercise program, stretch and cryotherapy (LSC), after simulated game pitching by collegiate baseball pitchers. **Design:** Repeated measures cross-over design. **Setting:** Research laboratory. **Participants:** 20 healthy male collegiate baseball pitchers (mean age 21.7 yrs \pm 1.41) were recruited to participate in this study; 18 pitchers completed all aspects of the study. **Interventions:** Each participant threw 3 innings of a simulated game (a total of 45 pitches) and then was randomly assigned to receive either the SC or LSC post-pitching treatment method. The participants returned to the laboratory at 24 and 48 hour intervals after the simulated game pitching to provide follow-up measures of glenohumeral joint strength and PROM, and patient-oriented measures of functional ability and pain. Two weeks later, each

participant repeated an identical bout of simulated game pitching, was treated with the alternate recovery method, and returned to the lab for follow-up data collection at 24 and 48 hours intervals. **Main Outcome Measures:** Isometric glenohumeral internal and external rotation strength and PROM measurements were obtained on four occasions with each treatment regimen. The velocity of every pitch thrown was measured with a radar gun, and later evaluated for accuracy via video analysis. A QuickDASH™ Sport questionnaire and a 100-mm visual analog pain scale (VAS) were also completed at 24 and 48 hour intervals post-pitching. **Results:** The LSC protocol produced significantly better patient outcomes than the SC protocol for 6 of the 9 objective and subjective measures, specifically, glenohumeral isometric strength, shoulder internal rotation PROM, total rotation PROM, pitching velocity, QuickDASH™ Sport score and VAS pain score ($p \leq 0.05$). **Conclusions:** The results of this study indicate that the LSC active recovery treatment regimen was more effective than the passive recovery SC method for post-pitching restoration of glenohumeral joint strength and PROM. Light shoulder exercise after pitching was found to be a superior post-pitching protocol for a more complete and rapid recovery of shoulder strength, PROM and pitching velocity in collegiate pitchers.

CHAPTER I

INTRODUCTION

A Major League Baseball (MLB) season consists of 162 games over the 6 month duration of the regular season, while the NCAA intercollegiate baseball season typically consists of 60 games played in a 4 month period. Currently, most MLB teams employ a 5 pitcher starting rotation, that is, each of the pitchers has one start (game) every 5 days. In contrast, collegiate baseball starting pitchers are generally on a 7 day-rotation. During their respective seasons, high demand relievers are pitching in games every other day or possibly as often as 2 or 3 days in a row. Moreover, the pitching frequency typically increases during MLB postseason playoffs and the World Series, as well as during NCAA postseason tournament and World Series games.

The localized muscular fatigue, acute loss of glenohumeral strength and passive range of motion (PROM), and delayed onset muscle soreness (DOMS) that intercollegiate and professional baseball pitchers experience following a game must be minimized or eliminated before they can safely pitch in their next outing. Bradbury and Forman found that the number of pitches thrown in the previous game affected the pitching performance of next game, and the number of pitches thrown is linearly related to decreases in strikeouts per 9 innings, and subsequent increases in home runs and walks per 9 innings, as well as earned run average.¹

In competitive baseball, a starting pitcher needs to recover from his pitching outing as rapidly as possible to maximize performance while minimizing the risk of

injury, and be ready for his scheduled start or game appearance. In the 2014 MLB season, several major league organizations considered increasing their 5-pitcher starting rotation to 6-man starting rotations due to ongoing concerns about the frequency of injury among major league pitchers.

The therapeutic recovery methods employed by athletic trainers after baseball pitching are very important to allow the pitchers to be ready for the next game, while reducing the risk of shoulder and elbow overuse injuries. Currently, the combination of light shoulder exercise, stretching, and ice is commonly used as a recovery method after baseball pitching to hasten the restoration of the pitcher's shoulder muscular strength and PROM, and reduce the symptoms of DOMS

Baseball pitching produces tremendous stresses on shoulder and elbow, and the chronic application of these loads over a period of years produces morphological changes glenohumeral joint structures while frequently inducing shoulder injuries. The baseball throwing motion has been shown to produce 67 N-m of internal rotation torque, and 64 N-m of elbow varus torque in the late cocking phase of pitching, and 97 N-m of glenohumeral horizontal abduction torque after ball release.^{2,3}

Maximum glenohumeral internal rotation instantaneous velocity has been measured at 6,100 to 7,900 degrees per second in collegiate and professional baseball pitchers, respectively.^{2,3} The chronic stresses placed on the shoulder and elbow during pitching induce loss of shoulder internal rotation⁴⁻⁶ and total glenohumeral range of motion⁷⁻⁹, glenohumeral internal rotation deficit (GIRD)⁷⁻¹⁰, instability of shoulder, and loss of strength in the shoulder muscles¹¹⁻¹⁴. Acute alterations of strength and PROM of glenohumeral joint after baseball pitching need to be recovered to prevent chronic change

of shoulder structures and reduce the risk of shoulder injuries.

Fatigue is a major casual factor of shoulder injuries among baseball pitchers.¹⁵ The shoulder muscles and surrounding structures have important roles to stabilize the shoulder, relying primarily on the rotator cuff muscles, glenohumeral labrum, and joint capsule to support a joint with large humeral head and small glenoid fossa of scapula.¹⁴ Fatigue affects shoulder strength and in turn, pitching velocity immediately after repetitive throwing.^{12,13} Weakened (fatigued) shoulder muscles have been shown to increase the incidence of throwing-related injuries that require surgical repairs.¹¹

The inability to voluntarily activate the infraspinatus muscle is the sign of external rotation muscle weakness due to fatigue from throwing.¹² Gandhi et al. reported a significant (13%) decrease in voluntary infraspinatus activation among high school baseball pitchers due to fatigue after an average of 87 pitches in the game.¹² Furthermore, in a study of 13 collegiate and minor league professional pitchers, significant losses in arm strength was reported by Mullaney after approximately 7 innings and/or throwing 100 pitches.¹³ College and minor league baseball starting pitchers threw an average of 99 ± 29 pitches in the games that were monitored as part of the Mullaney study. After approximately 100 pitches thrown, Mullaney noted average glenohumeral strength losses of 18% in internal rotation, 15% in flexion, 12% in abduction, and 11% in external rotation and adduction compared with strength measurements obtained 1 to 2 days before the pitching outings.¹³ Losing muscle strength means that the pitchers lose the support of the glenohumeral joint dynamic stabilizers which in turn increases the stresses on the shoulder and elbow joints.

In addition, Byram et al.¹¹ concluded that preseason weakness of external rotators and supraspinatus among baseball pitchers increases the risk of throwing-related injuries that require surgical intervention.¹¹ These authors reported strong, statistically-significant correlations between prone glenohumeral joint external rotation weakness, seated external rotation weakness, and supraspinatus weakness, and the throwing-related injuries requiring surgery.¹¹

Baseball pitchers need to maintain the delicate balance of the stability and mobility of shoulder for optimal performance.^{5,16,17} The presence of an optimal balance of shoulder internal rotation and external rotation PROM reduces the translation of center of humeral head rotation on the glenoid fossa of scapula.¹⁸ The balance of shoulder internal rotation and external rotation is altered by repetitive throwing in baseball pitchers, as they commonly are found to have excessive external rotation and limited internal rotation PROM.

Posterior glenohumeral capsule tightness of shoulder is a common cause of the loss of shoulder internal rotation among elite baseball pitchers.¹⁹ Tightness of posterior capsule interferes with the proper throwing mechanics and can lead to the subacromial impingement, rotator cuff injuries, and glenohumeral joint capsule tears.²⁰ The increased external rotation PROM found among high-level pitchers is believed to be a necessary adaptation that results in improved mechanical advantage and increased pitching velocity.^{21,22} Total glenohumeral PROM, the sum of internal and external PROM, should be the same bilaterally even in the presence of decreased internal rotation and increased external rotation ROM in the pitching arm.⁹ However, maladaptation of glenohumeral joint can diminish the ideal shoulder movement and increase the injury risk.⁵

Glenohumeral internal rotation deficit (GIRD) and loss of total glenohumeral ROM have been shown to alter the normal kinematics of shoulder.^{10,23,24} The center of rotation of the humerus translates anterosuperiorly during shoulder forward flexion²³ and posterosuperiorly during external rotation and arm cocking phase of pitching.^{10,24} These abnormal humeral shifts on glenoid fossa can ultimately result in tears of the glenoid labrum.^{7,10,21,25}

Kibler and Reinold both observed that there will be an acute loss of shoulder internal rotation and total glenohumeral ROM immediately after pitching.^{5,6} Reinold et al.⁶ found that shoulder and elbow PROM decreased significantly immediately after only 50 to 60 full intensity pitches from a mound.⁶ Reinold et al. also observed decreases in passive shoulder internal rotation (-9.5°), total glenohumeral ROM (-10.7°), and elbow extension (-3.2°) after baseball pitching, and these deficits remained 24 hours after pitching.⁶

The causes of muscular stiffness of anatomical motions include inflammation and soft tissue edema in the perimysial and/or epimysial connective tissue elements following eccentric muscle activity.⁴ Pitching again before recovery from the acute muscle damage and loss of shoulder and elbow ROM places the pitcher at risk of injury. Kibler et al.⁵ investigated the acute changes in shoulder internal rotation, external rotation, and total glenohumeral ROM exhibited in 45 professional baseball pitchers (22 starting pitchers, 23 relief pitchers) after they pitched in baseball games. Shoulder internal and external rotation PROM were measured, and total glenohumeral ROM was calculated before warm-up or stretching, immediately after pitching, and then 24, 48, and 72 hours after pitching.⁵ The starting pitchers threw a maximum of 3 innings and 64 pitches, while the

relief pitchers threw a maximum of 2 innings and 41 pitches. Kibler et al. concluded that the average loss of internal rotation ROM after pitching (mean = -7°) did not return to baseline even after 72 hours of recovery time. The results of these two studies highlight the acute losses of shoulder PROM associated with pitching that must be recovered prior to elite baseball pitchers being safely ready to make their next appearance in a game.⁵

Delayed onset muscle soreness (DOMS) is one of the reasons for decreased flexibility, maximum force production, and performance. The primary cause of DOMS is large quantities of eccentric muscle activity that induce muscle damage.²⁶ The eccentric muscle actions of posterior rotator cuff muscles and biceps brachii during baseball throwing motion are considered the primary causes of posterior shoulder muscle soreness and tightness after baseball pitching. Common signs of DOMS include point tenderness to palpation, continuous pain, and general discomfort.^{26,27} Reducing DOMS is one of the key components of the recovery from strenuous activity.

Passive recovery is defined as a rest without activity in sitting, lying down quietly, and/or stretching.²⁸ Fifteen to 25 minutes of passive recovery has the effect of returning the decreased pH levels to normal after moderate intensity exercise.²⁹ Passive recovery has also been shown to reduce blood lactate concentrations.^{30,31}

In contrast, active recovery involves submaximal cardiovascular exercise that increases the blood flow to facilitate removal of the blood lactate.^{30,32} Blood lactate concentrations rates after the strenuous activities reduce more rapidly with active recovery than passive recovery.³³ The most effective clearance of blood lactate occurs when the intensity of exercise near the lactate threshold.³³

Light cardiovascular exercise³⁴, shoulder and forearm stretching, and cryotherapy³⁴⁻³⁸ are commonly used as a recovery and maintenance methods for baseball pitchers after pitching in games, warming up in the bullpen, and simulated games. Yanagisawa et al.³⁴ compared 4 recovery methods: (a) ice treatment for 20 minutes, (b) light shoulder exercise with upper body ergometer (UBE) for 20 minutes, (c) ice treatment with light shoulder exercise, and (d) a control condition on shoulder ROM and muscle cross-sectional area (mCSA) after baseball pitching.³⁴ These authors concluded that the ice and light shoulder exercise regimen was the most effective recovery method to reduce post-pitching edema and shoulder tightness.³⁴

To our knowledge, the Yanagisawa article is the only published study to have investigated light shoulder exercise as an active recovery method following baseball pitching. In their study published 12 years ago, Yanagisawa et al³⁴ used a UBE for their light shoulder exercise protocol, a device that may or may not be available in every dugout or baseball stadium. Although they reported positive results, additional research is needed to confirm or refute their findings, and these new studies should use a form of light shoulder exercise that can be used on the field.

Glenohumeral internal rotation deficit (GIRD) and the acute loss of internal rotation due to baseball pitching can be relieved with regular stretching program focused on internal rotation and cross-body stretches.⁴⁰⁻⁴² The cross-body stretch significantly increased internal rotation PROM among individuals with GIRD. The shoulder internal rotation in the cross-body stretching group increased significantly ($+20.0^\circ \pm 12.0^\circ$; $p \leq 0.05$) during a 4 week study.⁴² Manske also found the significant shoulder internal rotation improvement (mean = $+15.4^\circ$) with the cross-body stretching technique after 4

weeks.⁴¹

Cryotherapy is the most common treatment for acute musculoskeletal injuries to reduce muscle damage after the activity at the athletic training settings.^{36,37} Baseball pitchers repeatedly expose their shoulders and elbows to microtrauma with each practice or game. There are number of positive effects to the acute injuries from the cryotherapy treatment. According to Snyder³⁸, cold therapy reduces blood flow, metabolic rate, hemorrhage, and edema formation. Secondary tissue death and muscular damage can be prevented by decreasing the demand of oxygen to the muscles so that the recovery time of tissue damage from the activity can be reduced.³⁵ Application of cryotherapy after the exercises is thought to reduce muscle tension, circulation, and inflammation by the effects of anesthesia, muscle spasm reduction, and muscle relaxation.³⁵

The effectiveness of light shoulder exercise programs for recovery after baseball pitching remains uncertain. Sports medicine clinicians need to know the effectiveness of light shoulder exercise and any therapeutic benefits need to be verified to use the method as a recovery and maintenance method after the baseball pitching.

The purpose of this study was to compare the effectiveness of a passive recovery method, stretching and cryotherapy (SC), with an active recovery protocol consisting of light shoulder exercise, stretching and cryotherapy (LSC), after simulated game pitching by collegiate baseball pitchers.

We hypothesized that there will be statistically significant differences observed in the objective measures (glenohumeral joint muscular strength and PROM) and patient-oriented measures (QuickDASH™ and VAS pain scale) with the LSC protocol when compared to the results of the SC post-pitching recovery method ($p \leq 0.05$).

Following the completion of this thesis, an abstract of the findings will be submitted by November 15, 2015 for a peer-reviewed presentation at the 2016 annual meeting of the National Athletic Trainers' Association to be held in Baltimore, Maryland in June 2016. In the interim, the primary manuscript from this thesis will be submitted for publication to the *Journal of Athletic Training*.

CHAPTER II

MANUSCRIPT

COMPARISON OF THE EFFECTS OF TWO RECOVERY METHODS
AFTER COLLEGIATE BASEBALL PITCHING

Hiroto Kawamura, B.S., ATC, LAT, CES

Rod A. Harter, Ph.D., ATC, LAT, FNATA

Luzita I. Vela, Ph.D., ATC, LAT

Kevin McCurdy, Ph.D., CSCS

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Journal of Athletic Training

Abstract

Context: The localized muscular fatigue, acute loss of glenohumeral strength and passive range of motion (PROM), and delayed onset muscle soreness (DOMS) that intercollegiate and professional baseball pitchers experience following a game must be minimized or eliminated before they can safely pitch in their next outing. The combination of light shoulder exercise, stretching, and cryotherapy is commonly used after baseball pitching as the recovery method to hasten the restoration of shoulder muscular strength and PROM, and reduce the symptoms of DOMS. However, the effectiveness of the light shoulder exercise program for recovery after baseball pitching remains uncertain. **Objective:** To compare the effectiveness of two recovery methods, stretch and cryotherapy (SC), and a light shoulder exercise program, stretch and cryotherapy (LSC), after simulated game pitching by collegiate baseball pitchers. **Design:** Repeated measures cross-over design. **Setting:** Research laboratory. **Participants:** 20 healthy male collegiate baseball pitchers (mean age, 21.7 ± 1.41 yrs; height, 1.85 ± 0.061 m; mass, 88.3 ± 8.76 kg) were recruited to participate in this study; 18 pitchers completed all aspects of the study. **Interventions:** Each participant threw 3 innings of a simulated game (a total of 45 pitches) and then was randomly assigned to receive either the SC or LSC post-pitching treatment method. The participants returned to the laboratory at 24 and 48 hour intervals after the simulated game pitching to provide follow-up measures of glenohumeral joint strength and PROM, and complete patient-oriented measures of functional ability and pain level. Two weeks later, each participant repeated an identical bout of simulated game pitching and was treated with the alternate recovery method, again returning to the lab for follow-up data collection at 24 and 48 hours intervals. **Main**

Outcome Measures: Isometric glenohumeral internal and external rotation strength and PROM measurements were obtained on 4 occasions with each treatment regimen. The velocity and accuracy of every pitch thrown were also measured and recorded. A QuickDASH™ questionnaire and a 100-mm visual analog pain scale (VAS) were completed by the participants at 24 and 48 hours post-pitching. **Results:** The LSC protocol produced significantly better patient outcomes than the SC protocol for 6 of the 9 objective and subjective measures, i.e., glenohumeral isometric strength, shoulder internal rotation PROM, total rotation PROM, pitching velocity, QuickDASH™ Sport score, VAS pain score ($p \leq 0.05$). **Conclusions:** The LSC treatment regimen was more effective for post-pitching recovery of glenohumeral strength and PROM than the SC method. Light shoulder exercise after pitching was found to be a superior post-pitching protocol for a more complete and rapid recovery of shoulder strength, PROM and pitching velocity in collegiate pitchers.

Word Count: 428

Key Words: light shoulder exercise, cryotherapy, stretching, post-pitching recovery

Introduction

A Major League Baseball (MLB) season consists of 162 games over the 6 month duration of the regular season, while the NCAA intercollegiate baseball season typically consists of 60 games played in a 4 month period. Currently, most MLB teams employ a 5 pitcher starting rotation, that is, each of the pitchers has one start (game) every 5 days. In contrast, collegiate baseball starting pitchers are generally on a 7 day-rotation. During their respective seasons, high demand relievers are pitching in games every other day or possibly as often as 2 or 3 days in a row. Moreover, the pitching frequency typically increases during MLB postseason playoffs and the World Series, as well as during NCAA postseason tournament and World Series games.

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In competitive baseball, a starting pitcher needs to recover from his pitching outing as rapidly as possible to maximize performance while minimizing the risk of injury, and be ready for his scheduled start or game appearance. In the 2014 MLB season, several major league organizations considered increasing their 5-pitcher starting rotation to 6-man starting rotations due to ongoing concerns about the frequency of injury among

major league pitchers.

The therapeutic recovery methods employed by athletic trainers after baseball pitching are very important to allow the pitchers to be ready for the next game, while reducing the risk of shoulder and elbow overuse injuries. Currently, the combination of light shoulder exercise, stretching, and ice is commonly used as a recovery method after baseball pitching to hasten the restoration of the pitcher's shoulder muscular strength and PROM, and reduce the symptoms of DOMS.

Baseball pitching produces tremendous stresses on shoulder and elbow, and the chronic application of these loads over a period of years produces morphological changes glenohumeral joint structures while frequently inducing shoulder injuries. The baseball throwing motion has been shown to produce 67 N-m of internal rotation torque, and 64 N-m of elbow varus torque in the late cocking phase of pitching, and 97 N-m of glenohumeral horizontal abduction torque after ball release.^{2,3}

Maximum glenohumeral internal rotation instantaneous velocity has been measured at 6,100 to 7,900 degrees per second in collegiate and professional baseball pitchers, respectively.^{2,3} The chronic stresses placed on the shoulder and elbow during pitching induce loss of shoulder internal rotation⁴⁻⁶ and total glenohumeral range of motion⁷⁻⁹, glenohumeral internal rotation deficit (GIRD)⁷⁻¹⁰, instability of shoulder, and loss of strength in the shoulder muscles¹¹⁻¹⁴. Acute alterations of strength and PROM of glenohumeral joint after baseball pitching need to be recovered to prevent chronic change of shoulder structures and reduce the risk of shoulder injuries.

Fatigue is a major casual factor of shoulder injuries among baseball pitchers.¹⁵ The shoulder muscles and surrounding structures have important roles to stabilize the

shoulder, relying primarily on the rotator cuff muscles, glenohumeral labrum, and joint capsule to support a joint with large humeral head and small glenoid fossa of scapula.¹⁴ Fatigue affects shoulder strength and in turn, pitching velocity immediately after repetitive throwing.^{12,13} Weakened (fatigued) shoulder muscles have been shown to increase the incidence of throwing-related injuries that require surgical repairs.¹¹

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In addition, Byram et al. concluded that preseason weakness of external rotators and supraspinatus among baseball pitchers increases the risk of throwing-related injuries that require surgical intervention. These authors reported strong, statistically-significant correlations between prone glenohumeral joint external rotation weakness, seated

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Posterior glenohumeral capsule tightness of shoulder is a common cause of the loss of shoulder internal rotation among elite baseball pitchers.¹⁹ Tightness of posterior capsule interferes with the proper throwing mechanics and can lead to the subacromial impingement, rotator cuff injuries, and glenohumeral joint capsule tears.²⁰ The increased external rotation PROM found among high-level pitchers is believed to be a necessary adaptation that results in improved mechanical advantage and increased pitching velocity.^{21,22} Total glenohumeral ROM, the sum of internal and external ROM should be the same bilaterally even in the presence of decreased internal rotation and increased external rotation ROM in the pitching arm.⁹ However, maladaptation of glenohumeral joint can diminish the ideal shoulder movement and increase the injury risk.⁵

Glenohumeral internal rotation deficit (GIRD) and loss of total glenohumeral ROM have been shown to alter the normal kinematics of shoulder.^{10,23,24} The center of rotation of the humerus translates anterosuperiorly during shoulder forward flexion²³ and posterosuperiorly during external rotation and arm cocking phase of pitching.^{10,24}

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Kibler and Reinhold both observed that there will be an acute loss of shoulder internal rotation and total glenohumeral ROM immediately after pitching.^{5,6} Reinold et al.⁶ found that shoulder and elbow PROM decreased significantly immediately after only 50 to 60 full intensity pitches from a mound.⁶ Reinold et al. also observed decreased passive shoulder internal rotation (-9.5°), total glenohumeral ROM (-10.7°), and elbow extension (-3.2°) after baseball pitching, and these deficits remained 24 hours after the pitching.⁶

Among the causes of muscular stiffness of anatomical motions are inflammation and soft tissue edema in the perimysial and/or epimysial connective tissue elements following eccentric muscle activity.⁴ Pitching again before full recovery from the acute muscle damage and loss of shoulder and elbow ROM places the pitcher at risk of injury. Kibler et al. investigated the changes in shoulder internal rotation, external rotation, and total glenohumeral ROM exhibited in 45 professional baseball pitchers (22 starting pitchers, 23 relief pitchers) after they pitched in baseball games. Shoulder internal rotation and external rotation PROM were measured, and total glenohumeral ROM calculated before warm-up or stretching, immediately after pitching, and then 24, 48, and 72 hours after pitching.⁵ The starting pitchers threw a maximum of 3 innings and 64 pitches, and the relief pitchers threw a maximum of 2 innings and 41 pitches. Kibler et al. concluded that the average loss of internal rotation ROM after pitching (mean = -7°) did not return to the baseline even after 72 hours of recovery time. The results of these two studies highlight the acute losses of shoulder PROM associated with pitching that must

be recovered prior to elite baseball pitchers being safely ready to make their next appearance in a game.⁵

Delayed onset muscle soreness (DOMS) is one of the factors of decreasing flexibility, maximum force production, and performance. The primary cause of DOMS is large quantities of eccentric muscle activity that induce muscle damage.²⁶ The eccentric muscle actions of posterior rotator cuff muscles and biceps brachii during baseball throwing motion are considered the primary causes of posterior shoulder muscle soreness and tightness after baseball pitching. Common signs of DOMS include point tenderness to palpation continuous pain, and general discomfort.^{26,27} Reducing DOMS is one of the key components of the recovery from strenuous activity to maintain optimal performance.

Passive recovery is defined as a rest without activity in sitting, lying down quietly, and/or stretching²⁸ Fifteen to 25 minutes of passive recovery has the effect of returning the decreased pH levels to normal after moderate intensity exercise.²⁹ Passive recovery has also been shown to reduce elevated blood lactate concentrations.^{30,31}

In contrast, active recovery is involved submaximal cardiovascular exercise that increases the blood flow to facilitate removal of the blood lactate.^{30,32} Blood lactate concentrations rates after the strenuous activities were better with active recovery than passive recovery.³³ The most effective clearance of blood lactate occurred at the intensity of exercise near the lactate threshold.³³

Light cardiovascular exercise³⁴, shoulder and forearm stretching, and cryotherapy³⁴⁻³⁸ are commonly used as a recovery and maintenance methods for baseball pitchers after pitching in games, warming up in the bullpen, and simulated games. Yanagisawa et al.³⁴ compared 4 recovery methods: (a) ice treatment for 20 minutes, (b)

light shoulder exercise³⁹ with upper body ergometer (UBE) for 20 minutes, (c) ice treatment with light shoulder exercise, and (d) a control condition on shoulder ROM and muscle cross-sectional area (mCSA) after baseball pitching.³⁴ These authors concluded that the ice and light shoulder exercise regimen was the most effective recovery method to reduce post-pitching edema and shoulder tightness.³⁴

To our knowledge, the Yanagisawa article is the only published study to have investigated light shoulder exercise as an active recovery method following baseball pitching. In their study published 12 years ago, Yanagisawa et al³⁴ used a UBE for their light shoulder exercise protocol, a device that may or may not be available in every dugout or baseball stadium. Although they reported positive results, additional research is needed to confirm or refute their findings, and these new studies should use a form of light shoulder exercise that can be used on the field.

Glenohumeral internal rotation deficit and the acute loss of internal rotation due to baseball pitching can be relieved with regular stretching program focused on internal rotation and cross-body stretches.⁴⁰⁻⁴² The cross-body stretch improved significant increase the internal rotation of the subjects with GIRD. The shoulder internal rotation of the cross-body stretching group (mean \pm SD, $20.0^\circ \pm 12.0^\circ$) increased significantly in 4 weeks study.⁴² Manske also found the significant shoulder internal rotation ROM improvement (mean = $+15.4^\circ$) with the cross-body stretching technique after 4 weeks.⁴¹

Cryotherapy is the most common treatment for acute musculoskeletal injuries to reduce muscle damage after the activity at the athletic training settings.^{36,37} Baseball pitchers repeat microtrauma to shoulder and elbow from each baseball pitching. There are number of positive effects to the acute injuries from the cryotherapy treatment.

According to Snyder³⁸, cold therapy reduces the blood flow, metabolic rate, hemorrhage, and edema formation. Secondary tissue death and muscular damage can be prevented by decreasing the demand of oxygen to the muscles so that the recovery time of tissue damage from the activity can be reduced.³⁵ Application of cryotherapy after the exercises is thought to reduce muscle tension, circulation, and inflammation by the effects of anesthesia, muscle spasm reduction, and muscle relaxation.³⁵

The effectiveness of light shoulder exercise programs for recovery after baseball pitching remains uncertain. Sports medicine clinicians need to know the effectiveness of light shoulder exercise and any therapeutic benefits need to be verified to use the method as a recovery and maintenance method after the baseball pitching.

As a personal clinical observation gleaned from two summers and one season spent as an athletic training intern with two different MLB clubs, many baseball players have mentioned that the recovery methods that include light shoulder exercise, shoulder stretch, and ice after pitching are effective to maintain the shoulder strength, stability and PROM, and DOMS and stiffness. However, the effectiveness of light shoulder exercise program for recovery after baseball pitching has not been systematically evaluated in a controlled setting. Sports medicine clinicians need to know the effectiveness of light shoulder exercise and the effectiveness needs to be verified to use the method as a recovery and maintenance method after the baseball pitching.

Therefore, the purpose of this study was to compare the effectiveness of a passive recovery method, stretching and cryotherapy (SC), with an active recovery protocol that consisted of light shoulder exercise, stretching and cryotherapy (LSC), after simulated game pitching by collegiate baseball pitchers.

We hypothesized that there will be statistically significant differences observed in the objective measures (glenohumeral joint muscular strength and PROM) and patient-oriented measures (QuickDASH™ Sport and VAS pain scale) with the LSC protocol when compared to the results of the SC post-pitching recovery method ($p \leq 0.05$).

Methods

Participants

Twenty healthy college-aged baseball pitchers were recruited to participate in this study. Each volunteer was screened to determine whether or not they met the inclusion and exclusion criteria. The volunteers who were recruited for participation in this study were healthy male baseball pitchers who are members of NCAA Division I, II, III intercollegiate, junior college baseball teams, and/or members of collegiate-level club sports baseball teams, ages 18 to 25 years of age. Additional inclusion criteria for participation in this study include: (a) being currently physically active, e.g., participate in 2 or more hours per week of moderate physical activity, and (b) being able to throw a baseball at a velocity of at least 70 mph. Volunteers who currently have an upper extremity musculoskeletal or neurological injury, or who have had orthopedic surgery within the past 12 months will be excluded from participation in this study. All pitchers who met all study requirements, they were asked to provide informed consent before the participation. Informed consent was obtained prior to any activities associated with this study. A total of 18 participants completed this study. Two participants could not complete the second phase of the study due to the academic schedule conflicts with their follow-up data collection dates.

Procedures

Each participant in this repeated measures study received 2 different recovery methods of treatment after pitching in 2 simulated baseball games. One protocol included shoulder stretching techniques and cryotherapy treatment (SC) method, while the other method involved a program of light shoulder exercise, shoulder stretching techniques, and cryotherapy treatment (LSC). All passive shoulder joint stretches were performed by the principal investigator (HK), a certified athletic trainer. For the cryotherapy treatment, all participants had 3 ice packs (Cramer heavy duty ice bags, 0.25 x 0.46 m) applied over anterior shoulder, posterior shoulder, and elbow for 20 minutes at one time at the end of the treatment method.

The program of light shoulder exercise included standing shoulder abduction, standing full can, prone full can, prone horizontal abduction at 90° abduction with external rotation, prone extension with external rotation, prone external rotation at 90° abduction, prone row, and side-lying external rotation^{6,43} Each exercise was performed as 2 sets of 10 repetitions with 0.79 kg (2 pound) dumbbells. In addition, diagonal pattern internal rotation and external rotation, external rotation at 0° abduction, internal rotation at 0° abduction, and serratus punches at 120° were performed with manual resistance provided by the primary author.^{6,43}

The participants were randomly assigned to experience either the SC treatment first (n = 10) or the LSC regimen first (n = 10). Random assignment to groups was accomplished by having the participants pick one of two cards that were labeled “LSC treatment” and “SC treatment”. After 2 weeks of recovery time from the original pitching of the simulated game, each participant repeated the simulated game pitching and

received the treatment method not previously received.

With regard to the simulated game pitching, the participants warmed up by jogging for 5 minutes with easy pace (7 – 9 km/h) and then did 15 minutes of general whole-body warm-up that included dynamic stretching, static stretch as needed, weighed ball toss, and tubing exercises. Next, they threw 10 minutes of warm-up throws to simulate the warm-up that they would normally do prior to entering a baseball game. To induce DOMS, every participant threw 3 simulated innings that were each 15 pitches in duration, for a total of 45 pitches in the simulated game. All participants pitched at a rate of one pitch every 20 seconds, and then we imposed a 6 minute rest period between the simulated innings. As is typical of a real game situation, all participants also threw 5 to 8 pitches as a warm-up before each inning.

A portable indoor pitching mound was mounted 18.44 m (60.6 ft.) from a home plate and strike zone target in the half-indoor baseball practice facility under a roof and with the wall surrounding by tarpaulin. The velocity of each pitch was recorded using a radar gun (Stalker Sports 2, Stalker Rader, Plano, Texas) positioned behind the safety net, and the average velocity of fastballs was calculated. Every pitch was also video recorded with a camera positioned 5 m front and 1 m side from the home plate to document pitching accuracy and any changes to that accuracy during the simulated game.

Glenohumeral joint internal and external rotation isometric strength was measured with a handheld dynamometer (Lafayette Manual Muscle Tester, Lafayette, Indiana). Shoulder internal rotation and external rotation measures were obtained while the participant was lying supine on an examination table. The upper extremity was positioned at 90° shoulder abduction and 90° elbow flexion, and the forearm was aligned

perpendicular to the floor.¹³ The handheld dynamometer was placed on the palmar side of the wrist for the internal rotation test, and on the dorsal aspect of the wrist for the external rotation strength test.^{11,13,44} Each strength test was performed 3 times, and a 3-trial average force was calculated for each measure.

Scapular plane isometric abduction strength (“scaption”) was measured with the participant seated and the arm positioned at 90° shoulder abduction, 45° horizontal adduction and forearm neutral^{11,13,44}. Maximal scaption strength was assessed 3 times and a 3-trial average force was calculated.

Passive glenohumeral internal and external rotation ROM were measured in accordance with the Reinold et al. protocol⁶. Total glenohumeral motion was calculated the sum of internal rotation and external rotation. The measurements were performed 3 times for each anatomical motion with a digital goniometer (Baseline) and 3-trial averages were calculated. Two examiners, both ATs, were utilized to obtain the PROM measurements, one to position the shoulder and arm of the participant, and the other to correctly position and read the digital goniometer values.

The participants were asked to lie supine on an examination table with one of their arms at 90° of abduction and 10° of horizontal adduction in the plane of scapular with the aid of a small towel roll.^{8,43} The examiner stabilized the scapula with one hand on the table and passively externally rotated or internally rotated the arm, holding the participant’s wrist with the other hand.^{8,43} The upper extremity was held at the full ROM until full capsular or bony end feel was perceived.⁶ The examiner did not stabilize the humeral head to avoid the alternation of shoulder arthrokinematics.⁶ The other examiner aligned a baseline digital goniometer with two built-in levels; fulcrum over the olecranon

process, stationary arm perpendicular to the floor, and moving arm along the ulnar to the ulnar styloid process.⁴⁵ All measurements were performed within 30 minutes of pitching.⁶

For both the active and passive recovery treatment protocols, all strength and PROM measurements were performed on four occasions: before pitching, immediately after pitching, 24 hours after pitching the simulated game, and 48 hours pitching the simulated game.

During each of their visits to the laboratory, participants were asked to complete the patient-oriented 100-mm visual analog pain scale and QuickDASH™ Sports questionnaire before pitching, immediately after pitching the simulated game, and at 24 hours and 48 hours pre and post-pitching.

Experimental Design and Statistical Analysis

We employed a repeated measures crossover design with this cohort study. We believe that the planned 2-week interval between the participants' pitching of a simulated 3-inning baseball game and the effects of receiving a treatment protocol would be completely washed out prior to the second simulated pitching event and subsequent therapeutic intervention.

The independent variables for this study were Treatment (n = 2; shoulder stretching and cryotherapy (SC) treatment, and light shoulder exercise program, shoulder stretching, and cryotherapy (LSC) treatment), and Time (n = 4; before pitching, immediately after pitching, 24 hours after pitching, and 48 hours after pitching for 6 of the 10 outcome measures).

The key outcome measures in this study were glenohumeral external rotation and internal rotation PROM, total glenohumeral rotation PROM, glenohumeral internal and

external rotation isometric strength, scaption isometric strength, 100-mm VAS pain scale and QuickDASH™ Sports scores.

Means and standard deviations for all measurements were calculated.

SuperANOVA by Abacus Concepts used for all statistical analyses. Two-way (Treatment (2) x Time (4) repeated measures analysis of variance (ANOVA) were used as the statistical tests to analyze the strength and ROM before and after pitching in this study. Six of the outcome measures had 4 time points—before pitching the simulated game, immediately after pitching the simulated game, 24 hours after the simulated game, and 48 hours after the simulated game. Pitching velocity and accuracy were measured at 5 time points—inning 1, inning 2, inning 3, pitching at 24 hours after the simulated game, and pitching at 48 hours after the simulated game. Participants completed the VAS pain scale and the QuickDASH™ Sports questionnaire on 6 occasions—before pitching, immediately after pitching the simulated game, before and after pitching 24 hours after pitching the simulated game, and before and after pitching 48 hours after pitching the simulated game. In the presence of significant main effects for Time, Scheffé *post-hoc* mean comparisons were done at each time point between LSC and SC according to Winer.²² The statistical significance level was set *a priori* at $p \leq 0.05$.

Results

Passive Range of Motion

Glenohumeral Internal Rotation PROM

The means and standard deviations for the LSC and SC treatments for shoulder PROM at each time point are reported in Table 1. The time course of change in mean

shoulder PROM is plotted in Figure 1. The two-way repeated measures ANOVA for passive glenohumeral internal rotation ROM revealed a significant main effect of Time [$F(2.27, 38.63) = 8.240, p = 0.001$]. There was no significant Treatment x Time interaction [$F(2.21, 37.60) = 3.025, p = 0.056$]. One of mean comparisons between the treatments was significant ($p = 0.001$) for internal rotation PROM at 48 hours after pitching a simulated game.

Glenohumeral External Rotation PROM

The two-way repeated measures ANOVA for passive glenohumeral external rotation PROM revealed a significant main effect for Time [$F(3,51) = 3.602, p = 0.019$] (Figure 2). However, none of the mean comparisons between groups were significant for external rotation PROM during the time course of the study ($p > 0.05$).

Table 1. – Experimental Results for Glenohumeral Joint PROM

Parameters		T1	T2	T3	T4
Shoulder PROM (°)					
Internal Rotation ^a	LSC	50.48 ± 9.50	47.33 ± 10.72	47.61 ± 10.49	50.52 ± 10.08
	SC	50.09 ± 7.35	45.63 ± 8.94	46.16 ± 9.04	44.57 ± 8.08
External Rotation	LSC	111.24 ± 9.12	110.22 ± 10.79	107.81 ± 11.59	109.00 ± 10.21
	SC	111.88 ± 8.94	108.88 ± 10.29	109.69 ± 9.12	108.31 ± 9.72
Total Rotation ^a	LSC	161.72 ± 11.33	157.57 ± 14.46	155.41 ± 18.00	159.52 ± 17.60
	SC	161.97 ± 11.64	154.51 ± 14.12	155.84 ± 13.46	152.87 ± 11.49

Values are mean ± SD. T1, Pre-Pitching; T2, Post-Pitching simulated game; T3, 24 hours after pitching T4, 48 hours after pitching; LSC, Light Shoulder Exercise, Stretching , and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note ^a Main effect for Time ($p \leq .05$)

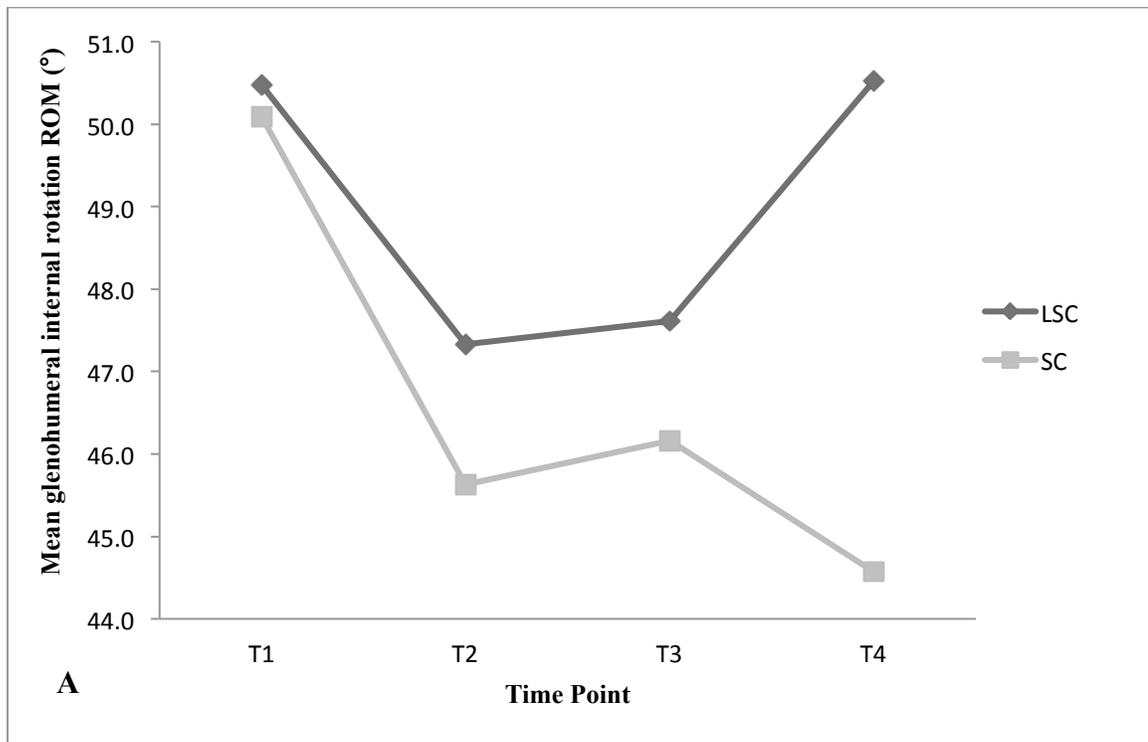


Figure 1. Glenohumeral internal rotation PROM at 90/90 supine. Y-axis = mean range of motion measurement (°); X-axis = time points; T1, pre-pitching simulated game; T2, post-pitching simulated game; T3, 24 hours after pitching simulated game; T4, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note: Significant simple main effect for Treatment at T4 period ($p \leq .05$).

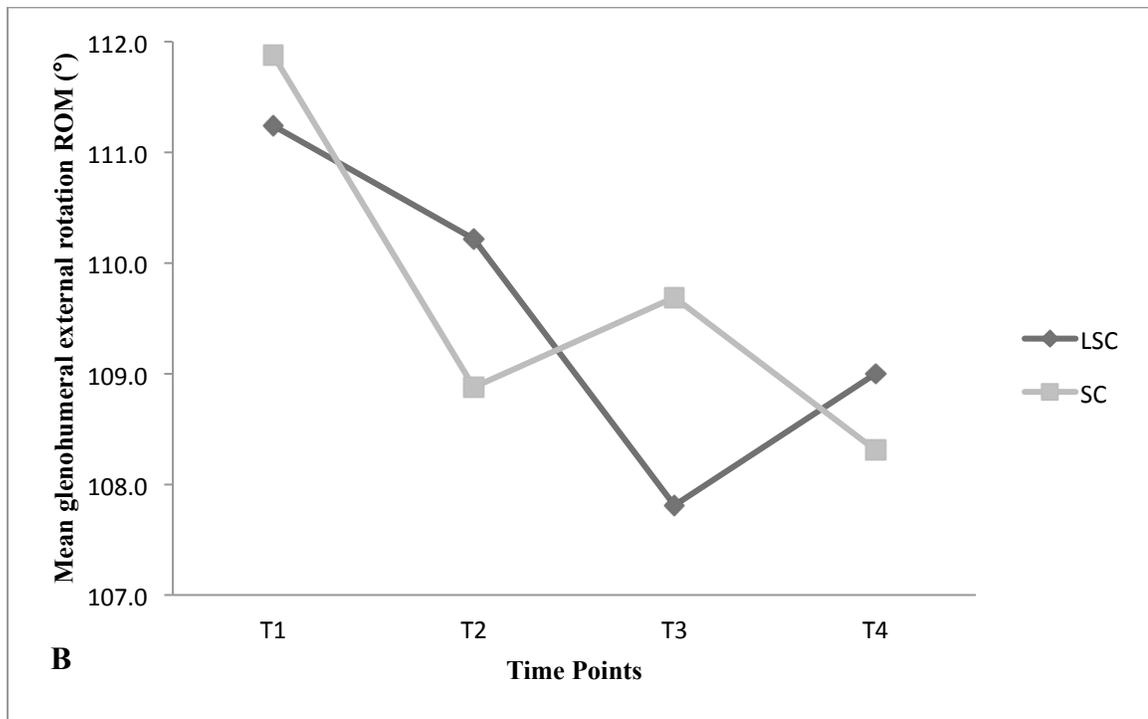


Figure 2. Glenohumeral external rotation PROM at 90/90 supine. Y-axis = mean range of motion measurement (°); X-axis = time points; T1, pre-pitching simulated game; T2, post-pitching simulated game; T3, 24 hours after pitching simulated game; T4, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Total Glenohumeral Rotation PROM

The two-way repeated measures ANOVA for total glenohumeral rotation PROM revealed a significant main effect for Time [$F(3,51) = 8.830, p = 0.001$]. One of the means comparisons between treatments was significant ($p = 0.007$) for total glenohumeral rotation ROM at 48 hours after pitching a simulated game (Figure 3).

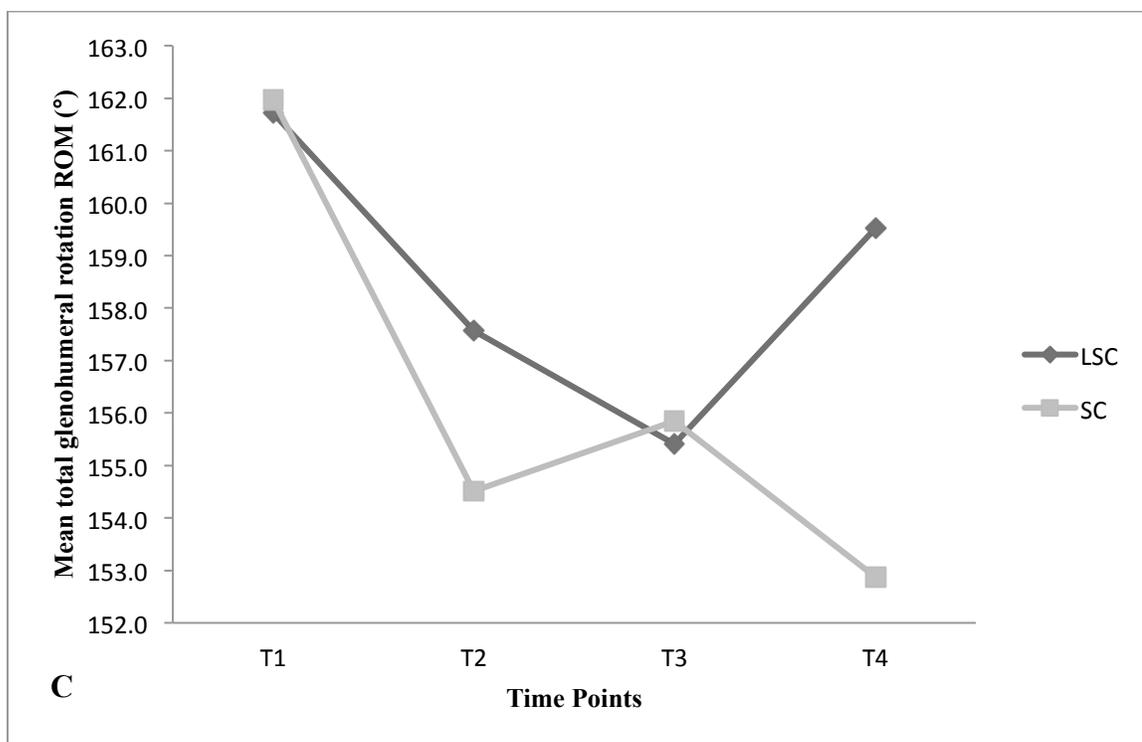


Figure 3. Total glenohumeral rotation PROM at 90/90 supine. Y-axis = mean range of motion measurement (°); X-axis = time points; T1, pre-pitching simulated game; T2, post-pitching simulated game; T3, 24 hours after pitching simulated game; T4, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note: Significant simple main effect for Treatment at T4 period ($p \leq .05$).

Isometric Shoulder Strength

Glenohumeral Internal Rotation Isometric Strength

The means and standard deviations for the LSC and SC treatments for shoulder strength at each time point are reported in Table 2. The time course of change in mean shoulder strength is reported in Figure 4. The two-way repeated measures ANOVA for shoulder internal rotation strength revealed significant main effect for Time [$F(3,51) = 10.875, p = 0.001$]. There was also a significant Treatment x Time interaction [$F(3,51) =$

3.557, $p = 0.021$]. One of mean comparisons between the treatments was significant ($p = 0.003$) for internal rotation strength at 48 hours after pitching a simulated game.

Table 2. – Experimental Results for Isometric Glenohumeral Joint Strength

Parameters		T1	T2	T3	T4
Shoulder Strength (N/kg)					
Internal Rotation ^{ab}	LSC	1.803 ± .282	1.632 ± .264	1.722 ± .288	1.824 ± .283
	SC	1.839 ± .317	1.667 ± .275	1.711 ± .309	1.702 ± .295
External Rotation ^{ab}	LSC	2.100 ± .412	1.982 ± .389	2.064 ± .412	2.137 ± .369
	SC	2.090 ± .374	2.016 ± .430	1.973 ± .382	1.975 ± .412
Scaption ^a	LSC	1.415 ± .232	1.366 ± .258	1.393 ± .276	1.438 ± .245
	SC	1.436 ± .236	1.364 ± .230	1.355 ± .250	1.357 ± .259

Values are mean ± SD. T1, Pre-Pitching; T2, Post-Pitching simulated game; T3, 24 hours after pitching T4, 48 hours after pitching; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note ^a Main effect for Time ($p \leq .05$). ^b Interaction effect for Treatment x Time ($p \leq .05$).

Glenohumeral External Rotation Isometric Strength

The two-way repeated measures ANOVA for shoulder external rotation strength revealed a significant main effect of time [$F(3,51) = 3.393, p = 0.025$]. There was also a significant Treatment x Time interaction present [$F(3,51) = 5.217, p = 0.003$]. Two of the mean comparisons between treatments were significantly different for external rotation strength at 24 hours ($p = 0.022$) and at 48 hours ($p = 0.001$) after pitching the simulated baseball game.

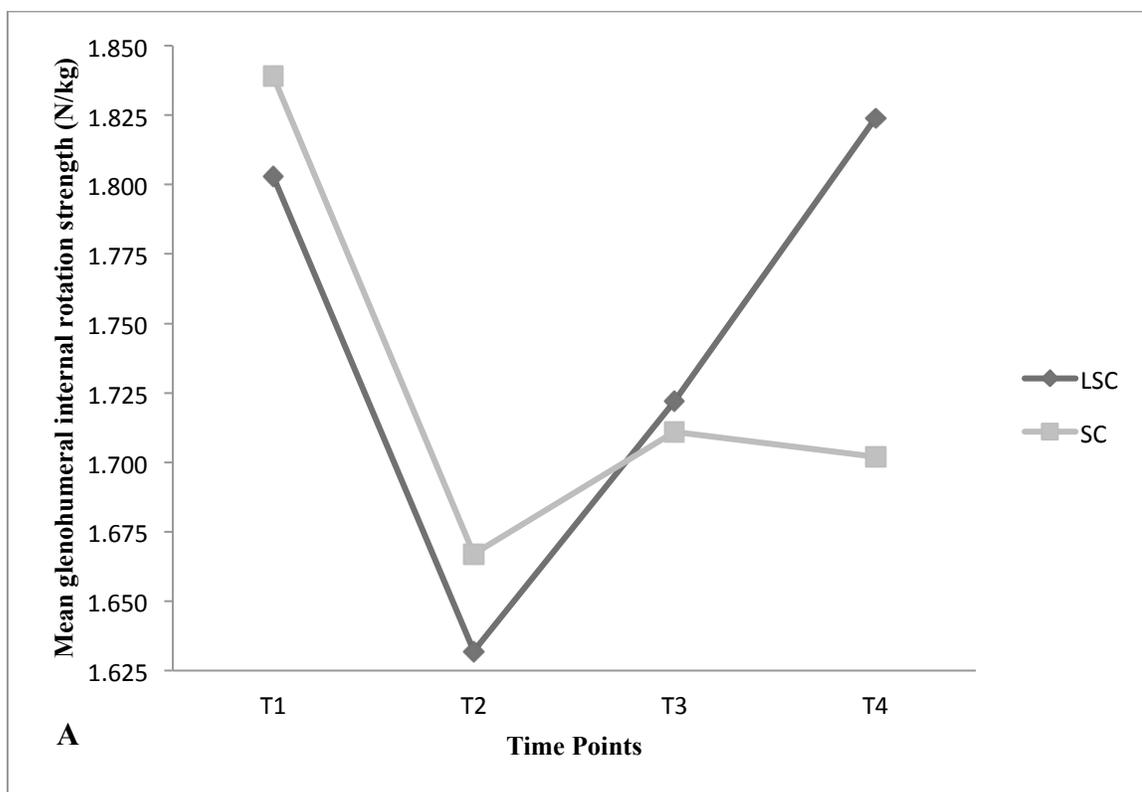


Figure 4. Glenohumeral isometric internal rotation strength at 90/90 supine. Y-axis = mean strength measurement (N/kg); X-axis = time points; T1, pre-pitching simulated game; T2, post-pitching simulated game; T3, 24 hours after pitching simulated game; T4, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note: Significant simple main effect for Treatment at T4 period ($p \leq .05$);
 Significant Treatment x Time interaction ($p \leq .05$)

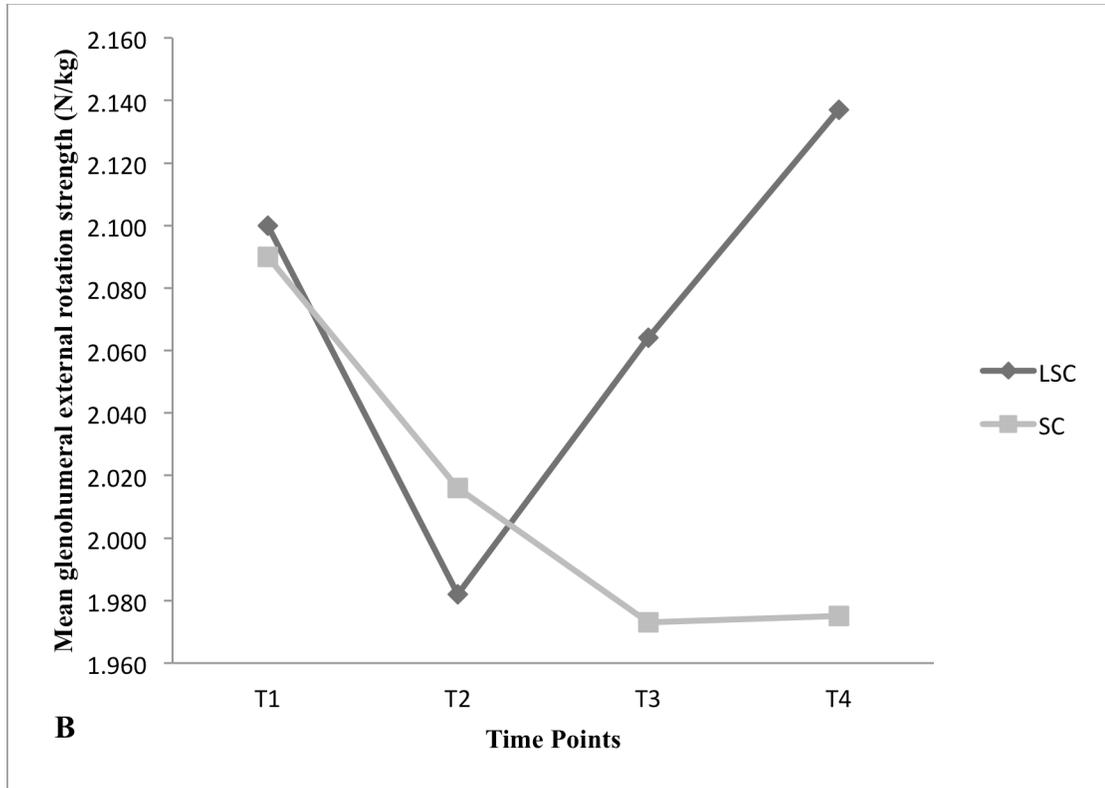


Figure 5. Glenohumeral isometric external rotation strength at 90/90 supine. Y-axis = mean strength measurement (N/kg); X-axis = time points; T1, pre-pitching simulated game; T2, post-pitching simulated game; T3, 24 hours after pitching simulated game; T4, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note: Significant simple main effect for Treatment at T4 period ($p \leq .05$);
 Significant Treatment x Time interaction ($p \leq .05$)

Glenohumeral Scaption Isometric Strength

The two-way repeated measures ANOVA for scaption strength indicated a significant main effect of Time [$F(2.17, 36.90) = 3.365, p = 0.042$]. One of the mean comparisons between treatments was significantly different for scaption strength at 48 hours after pitching a simulated game ($p = 0.026$).

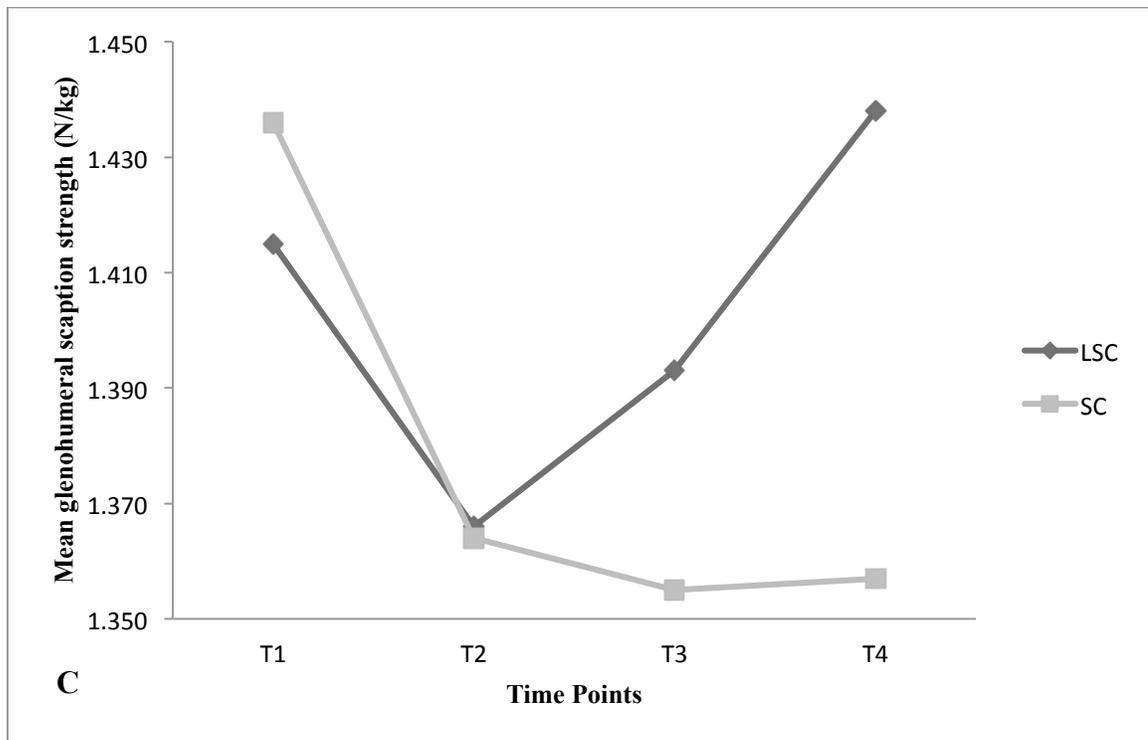


Figure 6. Glenohumeral isometric scaption strength while seated. Y-axis = mean strength measurement (N/kg); X-axis = time points; T1, pre-pitching simulated game; T2, post-pitching simulated game; T3, 24 hours after pitching simulated game; T4, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note: Significant simple main effect for Treatment at T4 period ($p \leq .05$);

Pitching Velocity

The means and standard deviations for the LSC and SC treatments for velocity at each time point are reported in Table 3. The time course of change in mean velocity is reported in Figure 7. The two-way repeated measures ANOVA for velocity revealed a non-significant main effect of treatment [$F(1,17) = 1.426, p = 0.249$] and a non-significant main effect of time [$F(2.15,36.52) = 2.161, p = 0.126$].

Table 3. – Experimental Results for Pitching Velocity and Accuracy

Parameters	Simulated Game				
	Inn-1	Inn-2	Inn-3	Post-24h	Post-48h
Velocity (km/h)					
LSC	120.50 ± 8.61	119.53 ± 8.24	119.40 ± 9.16	120.61 ± 9.95	122.08 ± 9.28
SC	120.80 ± 7.48	119.46 ± 7.96	118.06 ± 8.56	119.54 ± 9.92	120.07 ± 8.92
Accuracy (%)					
LSC	51.72 ± 15.23	49.78 ± 18.25	53.28 ± 14.11	59.44 ± 16.26	57.22 ± 21.64
SC	50.28 ± 18.28	48.83 ± 18.26	48.94 ± 13.01	53.33 ± 15.71	53.53 ± 18.69

Values are mean ± SD. Inn-1, Inning 1 of simulated game; Inn-2, Inning 2 of simulated game; Inn-3, Inning 3 of simulated game; Post-24h, 24 hours after pitching simulated game; Post-48h, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

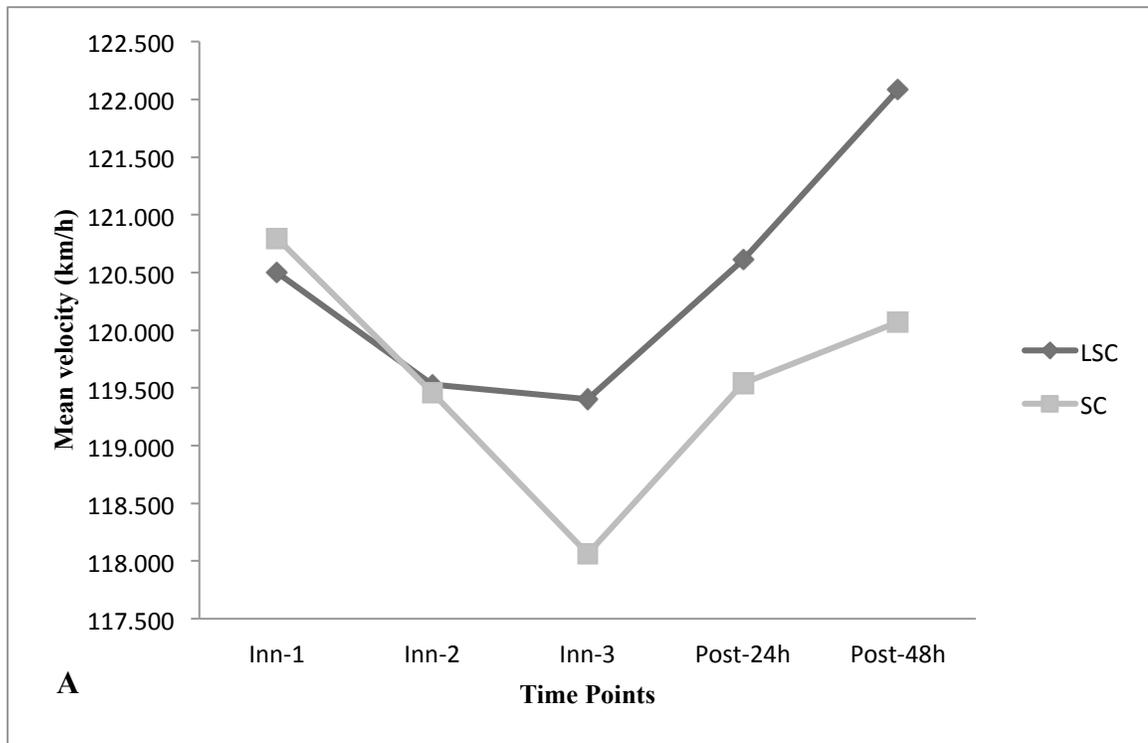


Figure 7. Pitching Velocity; Y-axis = mean velocity (km/h); X-axis = time points; Inn-1, Inning 1 in simulated game; Inn-2, Inning 2 in simulated game; Inn-3, Inning 3 in simulated game; Post-24h, 24 hours after pitching simulated game; Post-48h, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Pitching Accuracy

The means and standard deviations for the LSC and SC treatments for accuracy at each time point are also reported in Table 3. The time course of change in mean accuracy is reported in Figure 8. The two-way repeated measures ANOVA for accuracy revealed a non-significant main effect of treatment [$F(1,17) = 3.317, p = 0.086$] and a non-significant main effect of time [$F(4,68) = 1.945, p = 0.113$].

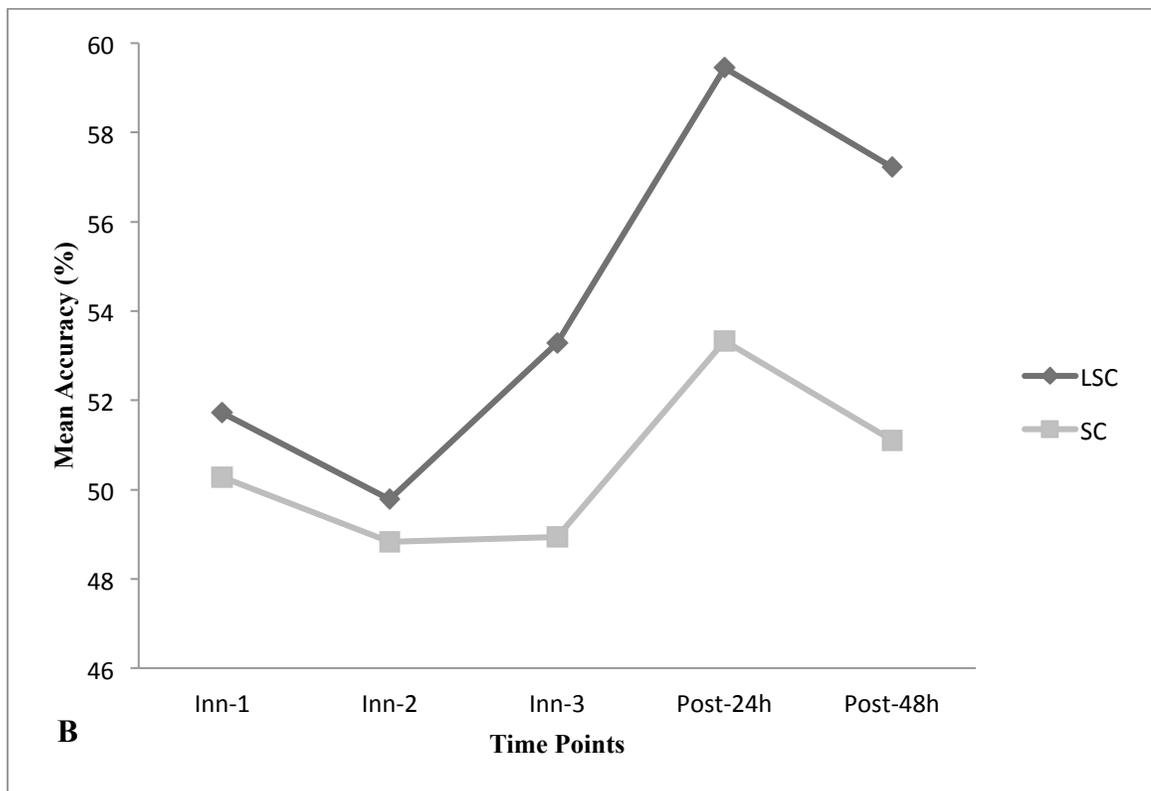


Figure 8. Pitching Accuracy; Y-axis = mean accuracy (%); X-axis = time points; Inn-1, Inning 1 in simulated game; Inn-2, Inning 2 in simulated game; Inn-3, Inning 3 in simulated game; Post-24h, 24 hours after pitching simulated game; Post-48h, 48 hours after pitching simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

100-mm Visual Analog Pain Scale (VAS)

The means and standard deviations for the LSC and SC treatments for VAS at each time point are reported in Table 4. The time course of change in mean VAS is reported in Figure 9. The two-way repeated measures ANOVA for VAS revealed a significant main effect of Time [$F(2.79, 47.46) = 10.089, p = 0.001$]. There was also a significant Treatment x Time interaction effect [$F(5, 85) = 3.632, p = 0.005$]. Three of the means comparisons between treatments were significant ($p = 0.026$) for VAS at post-pitching after 24 hours of a simulated game, ($p = 0.017$) at pre-pitching after 48 hours of a simulated game, and ($p = 0.017$) at post-pitching after 48 hours of a simulated game.

Table 4. – Experimental Results for VAS and QuickDASH™ Sports

	Simulated Game		24 Hours		48 Hours	
	Pre-1	Post-1	Pre-2	Post-2	Pre-3	Post-3
VAS (0-100) ^{ab}						
LSC	5.44 ± 6.81	24.06 ± 21.41	17.44 ± 13.65	21.39 ± 17.05	11.28 ± 9.80	17.94 ± 18.27
SC	4.67 ± 5.43	17.50 ± 17.72	17.89 ± 18.07	28.11 ± 23.14	18.50 ± 18.46	25.17 ± 19.23
QuickDASH Sports (0-100) ^{ab}						
LSC	7.99 ± 10.68	22.22 ± 18.22	15.63 ± 14.10	18.40 ± 15.23	10.07 ± 10.75	17.01 ± 17.78
SC	5.56 ± 8.27	12.50 ± 14.21	12.50 ± 16.87	19.44 ± 22.98	12.84 ± 14.61	18.75 ± 21.65

Values are mean ± SD. VAS, Visual Analog pain Scale; QuickDASH, Disability of the Arm, Shoulder and Hand; Pre-1, Pre pitching simulated game; Post-1, Post-pitching simulated game; Pre-2, Pre-pitching after 24 hours of simulated game; Post-2, Post-pitching after 24 hours of simulated game; Pre-3, Pre-pitching after 48 hours of simulated game; Post-3, Post-pitching after 48 hours of simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note ^a Main effect for Time ($p \leq .05$). ^b Interaction effect for Treatment x Time ($p \leq .05$).

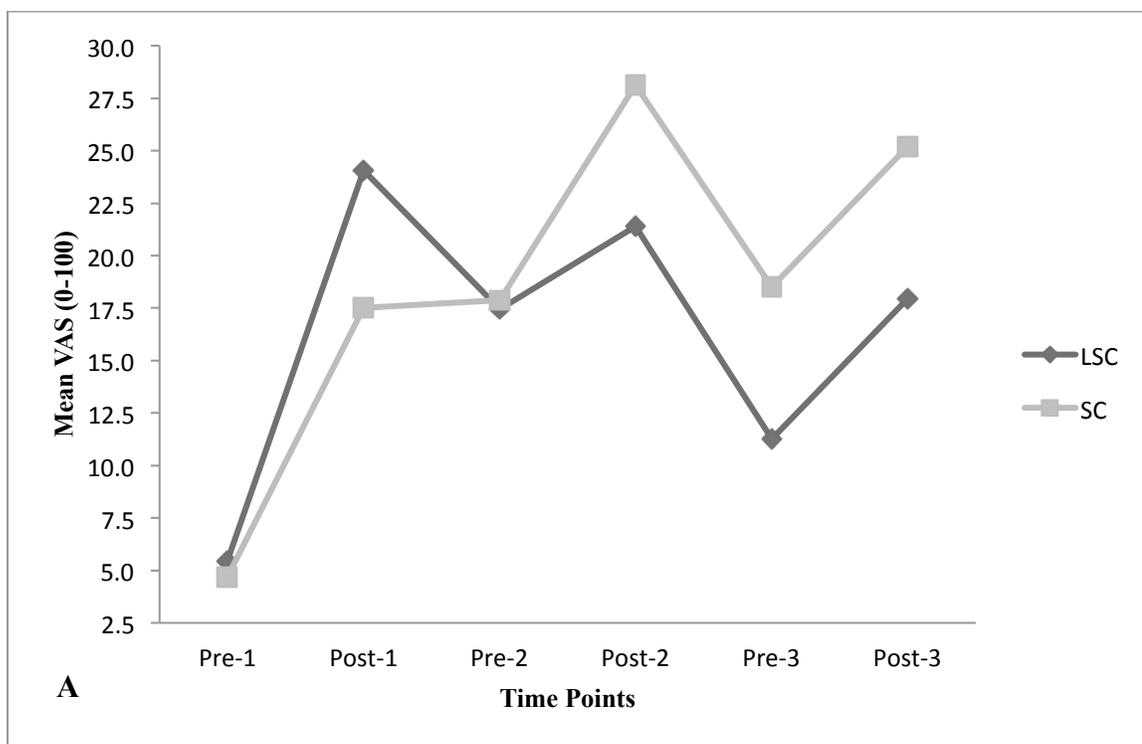


Figure 9. Visual Analog Pain Scale Results.; Y-axis = mean VAS score (0-100); X-axis = time points; Pre-1, Pre-pitching simulated game; Post-1, Post-pitching simulated game; Pre-2, Pre-pitching after 24 hours of simulated game; Post-2, Post-pitching after 24 hours of simulated game; Pre-3, Pre-pitching after 48 hours of simulated game; Post-3, Post-pitching after 48 hours of simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note: Significant simple main effect for Treatment at T4 period ($p \leq .05$);
 Significant Treatment x Time interaction ($p \leq .05$)

QuickDASH™ Sports Questionnaire

The means and standard deviations for the LSC and SC treatments for QuickDASH™ Sports at each time point are reported in Table 4. The time course of change in mean QuickDASH™ Sports score is reported in Figure 10. The two-way repeated measures ANOVA for QuickDASH™ Sports revealed a significant main effect for Time [$F(1.95, 33.13) = 5.306, p = 0.011$]. There was also a significant Treatment x Time interaction effect [$F(5, 85) = 2.853, p = 0.020$]. One of means comparisons between

treatments was significant ($p = 0.001$) for QuickDASH™ Sports score at post-pitching a simulated game.

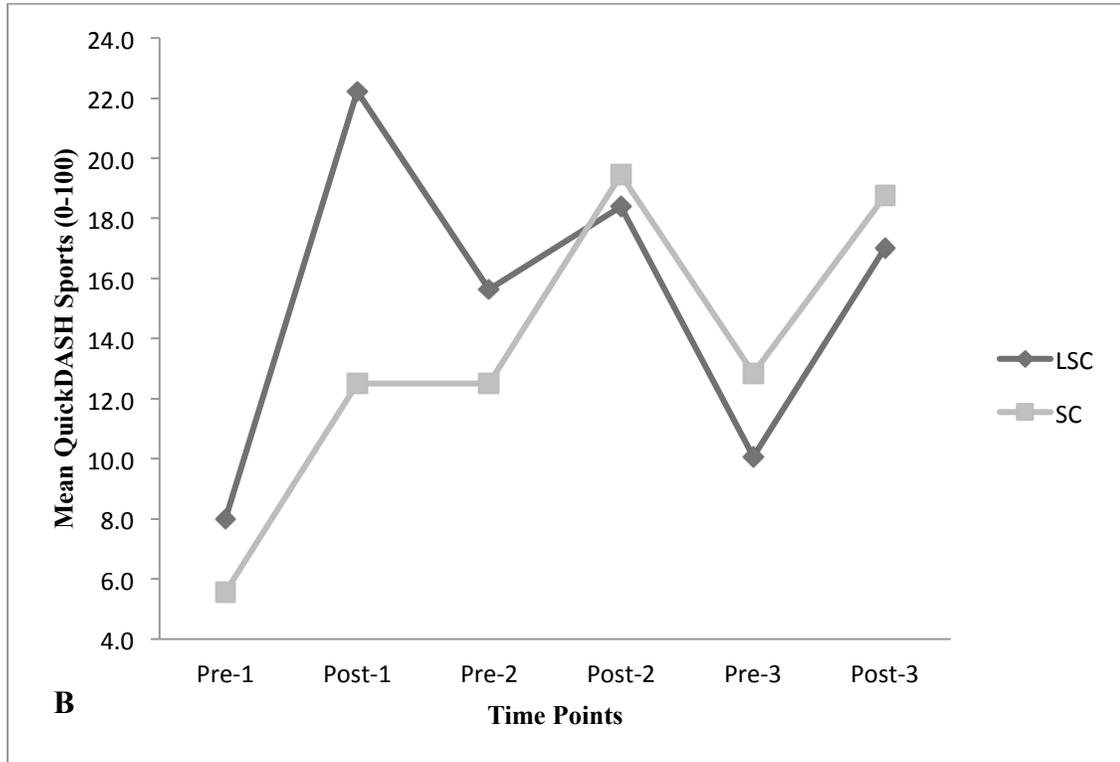


Figure 10. QuickDASH™ Sport; Y-axis = mean QuickDASH Sport score (0-100); X-axis = time points; Pre-1, Pre-pitching simulated game; Post-1, Post-pitching simulated game; Pre-2, Pre-pitching after 24 hours of simulated game; Post-2, Post-pitching after 24 hours of simulated game; Pre-3, Pre-pitching after 48 hours of simulated game; Post-3, Post-pitching after 48 hours of simulated game; LSC, Light Shoulder Exercise, Stretching, and Cryotherapy treatment; SC, Stretching and Cryotherapy treatment.

Note: Significant simple main effect for Treatment at T2 period ($p \leq .05$);
Significant Treatment x Time interaction ($p \leq .05$).

Discussion

Overall, our hypothesis that there would be statistically significant differences observed in the objective measures (glenohumeral joint muscular strength, PROM, velocity and accuracy) and subjective measures (QuickDASH and VAS pain scale) with the LSC protocol when compared to the results of the SC post-pitching recovery method ($p \leq 0.05$) was confirmed for most of variables (shoulder strength, shoulder internal rotation and total rotation ROM, velocity, and VAS pain scale).

Glenohumeral Isometric Strength

Our primary finding was that LSC was significantly more effective than the SC protocol for the post-pitching recovery of glenohumeral strength. The shoulder muscles have an important role as glenohumeral joint stabilizers.¹⁴ The glenohumeral joint relies heavily on rotator cuff muscles and surrounding muscles to stabilize and support the anatomically unstable glenohumeral joint.¹⁴ Weak glenohumeral joint stabilizers muscles are associated with throwing related injuries requiring surgical repairs.^{11,46,47} Diminished muscle strength after a pitching outing means that pitchers lose the support of the dynamic joint stabilizers and increase the stresses on their shoulder and elbow joints. Maintaining the strength of shoulder is critical to prevent shoulder injuries.

In the present study, LSC treatment showed better recovery of external rotation, internal rotation, and scaption strength than SC treatment. The means of all three isometric strength variables in LSC treatment at 48 hours after pitching a simulated game showed greater values than baseline before pitching. External rotation strength did not recover at the time point of 48 hours post-pitching of a simulated game with SC treatment.

Isometric internal rotation strength with LSC treatment was recovered after 48

hours of a simulated game (1.824 ± 0.283 N/kg) and stronger than pre-pitching (1.803 ± 0.282 N/kg) while the internal rotation strength with SC after 48 hours of a simulated game (1.702 ± 0.295 N/kg) had not yet returned to the baseline values (1.839 ± 0.317 N/kg). The means comparison between the treatments was significant ($p = .003$) for the internal rotation strength at 48 hours after pitching a simulated game.

The mean of external rotation strength with LSC treatment was recovered after 48 hours of a simulated game (2.137 ± 0.283 N/kg) and stronger than pre-pitching (2.100 ± 0.412 N/kg) while the external rotation strength with SC after 48 hours of a simulated game (1.975 ± 0.412 N/kg) did not recovered to the baseline (2.090 ± 0.374 N/kg). Two of the mean comparisons between treatments were significant ($p = 0.022$) for external rotation strength with LSC (2.064 ± 0.412 N/kg) and SC treatment (1.973 ± 0.382 N/kg) at 24 hours and ($p = 0.001$) at 48 hours after pitching a simulated game.

Moreover, the mean of scaption strength with LSC treatment was also recovered after 48 hours of a simulated game (1.438 ± 0.245 N/kg) and stronger than pre-pitching (1.415 ± 0.232 N/kg) while the internal rotation strength with SC after 48 hours of a simulated game (1.357 ± 0.259 N/kg) did not recovered to the baseline (1.436 ± 0.236 N/kg).

The results of this study revealed that the active recovery LSC treatment was more effective for the restoration of shoulder strength after pitching than the passive recovery SC treatment protocol. Shoulder strength needs to be treated properly to maintain strength of shoulder after baseball pitching and stability of shoulder while pitching baseball.

Glenohumeral Internal Rotation PROM

Internal rotation PROM in the LSC group was significantly greater ($50.52^{\circ} \pm 10.08^{\circ}$) than the SC group ($44.57^{\circ} \pm 8.08^{\circ}$) at 48 hours after pitching a simulated game. In our study, acute loss of shoulder internal rotation was similar to that which Kibler⁵, Reinold⁶, and Mullaney et al¹³ observed. Kibler et al⁵ concluded that the loss of internal rotation PROM after pitching (mean = -7°) did not return to the baseline even after 72 hours of recovery time.

Glenohumeral internal rotation PROM with SC treatment did not return to the baseline at 48 hours after pitching simulated game in this study; however, internal rotation PROM with LSC treatment returned to the baseline at 48 hours after pitching. Loss of throwing shoulder internal rotation compared with non-throwing arm, e.g., GIRD, is highly related to shoulder injuries in baseball players.^{7-10,16,17,48-50} The LSC treatment we employed was more effective than the SC protocol for recovery of shoulder internal rotation PROM after pitching. Shoulder internal rotation should be treated with LSC to maintain PROM and prevent chronic loss of shoulder internal rotation rather than SC treatment.

Total Glenohumeral PROM

Differences in total rotation of the throwing shoulder PROM compared with non-throwing shoulder is related to shoulder injuries.^{8,9} Wilk (2011) showed that pitchers with a total rotation difference greater than 5° have 2.5 times more chance to be injured. In this study, the total shoulder PROM in LSC treatment group was maintained within 2.20° at 48 hours after pitching a simulated game. However, the total shoulder PROM of SC group showed 9.10° difference at 48 hours after pitching. Mean comparisons between LSC ($159.52^{\circ} \pm 17.60^{\circ}$) and SC ($152.87^{\circ} \pm 11.49^{\circ}$) treatments were significant ($p =$

0.007) for total glenohumeral rotation PROM at 48 hours after pitching a simulated game. Maintaining the total glenohumeral rotation PROM as non-throwing arm is a key to prevent shoulder injuries for baseball pitchers and the LSC treatment was a better treatment to maintain total shoulder rotation.

Patient-Oriented Outcome Measures

The symptoms of DOMS include tenderness to palpation and/or movement, pain, discomfort, decreased flexibility, decreased maximum force production, and diminished performance.^{26,27} Induced muscle soreness may affect the performance of baseball pitching, pitching mechanics, and physiological change. Reducing and inhibiting DOMS are one of the key components of the recovery from strenuous activity to maintain optimal performance.

In the present study, our VAS pain scores revealed that LSC treatment reduced and inhibited DOMS after pitching compared with SC treatment. The VAS scores of both LSC and SC treatment had not recovered to the baseline after 48 hours of post-pitching a simulated game. However, LSC treatment had a tendency to recover from DOMS while SC treatment stayed constant value or worse. Three of the mean comparisons between treatments were significant ($p = 0.026$) for VAS at post-pitching after 24 hours of a simulated game, ($p = 0.017$) at pre-pitching after 48 hours of a simulated game, and ($p = 0.017$) at post-pitching after 48 hours of a simulated game. Light shoulder exercises appear to have helped reduce or inhibit DOMS after baseball pitching.

Pitching Performance Measures

Pitching velocity recovered better with the LSC treatment compared with SC treatment. The means comparison between treatments was significant ($p = 0.044$) for velocity at 48 hours after pitching a simulated game. There were no significant differences between treatments in pitching accuracy.

Limitations

There are some several important implications and limitations for this study. The effects of LSC and SC treatments after pitching could not be compared with a true control group with no treatment in this study. The effects of LSC and SC treatment need to be compared with the effects of no treatment after pitching to determine the true treatment effects.

Many of the outcome measures we collected and analyzed were not completely recovered during the 48 hour study period. Repeating this study with the addition of 72 hour and 96 hour post-pitching time periods would likely be sufficient for each treatment protocol to accomplish complete recovery from the simulated game.

The LSC and light shoulder exercise and stretch with no cryotherapy (LS) need to be compared to determine the cryotherapy effects. As a practitioner, it is hard to determine the frequency and duration of the best effects of cryotherapy based on pitch counts or innings for the best treatment effects. This study should be expanded to compare the effects of these and other post-pitching recovery strategies with various populations such professional baseball pitchers, various level of collegiate baseball pitchers, high school baseball pitchers, and adolescent pitchers.

Future studies should consider increasing the pitching volume to induce the additional DOMS symptoms. Conversely, future investigations might reduce the pitching volume to reduce the soreness after pitching based on the population. In the present study, 3 pitchers reported VAS pain scores less than 10 during the experiment, while 3 pitchers reported VAS pain scores greater than 65.

Lastly, this study showed the effects of light shoulder exercise on recovery of glenohumeral internal rotation, total glenohumeral ROM, shoulder strength, and DOMS. In the future, the frequency, duration, and necessity of cryotherapy based on pitch counts or innings needs to be determined. The ideal volume or intensity of light shoulder exercise after baseball pitching has not been experimentally determined. The different volumes of light shoulder exercises after pitching should be compared to identify the optimal volume of light shoulder exercises after pitching.

Conclusion

The results of this study suggest that LSC treatment was more effective than SC treatment for recovery from the DOMS symptoms that occurred as the result of pitching in a simulated baseball game. The addition of light shoulder exercises to the traditional stretching and cryotherapy after pitching was a superior treatment for recovering shoulder strength, PROM, and reducing the pain of DOMS.

The acute reduction of shoulder strength and PROM has been correlated with the incidence of shoulder injuries among baseball pitchers. To reduce the risk of shoulder injuries, the acute loss of glenohumeral muscular strength and range of motion must be recovered before baseball pitchers can be released to throw for the next game day or even

in practice. For professional health care providers, it will be better to treat baseball pitchers including light shoulder exercise for the quicker recovery from the pitching. When the athlete asked for the treatment after a baseball pitching outing, professional health care providers should apply not only stretching and cryotherapy, but also light shoulder exercises.

CHAPTER III

SUMMARY AND RECOMMENDATIONS FOR FUTURE STUDY

The purpose of this study was to compare the effectiveness of two recovery methods, stretching and cryotherapy (SC) versus light shoulder exercise program, stretching and cryotherapy (LSC), after simulated game pitching in collegiate baseball pitchers. The results of this study suggest that LSC treatment was more effective than SC treatment for the recovery after pitching in a simulated game. The addition of light shoulder exercise to the traditional stretching and cryotherapy after pitching was a superior treatment for recovering shoulder strength, shoulder internal rotation and total rotation PROM, velocity, and reducing the pain of DOMS.

The key outcome measures in this study were glenohumeral external rotation PROM, internal rotation PROM, horizontal adduction PROM, total glenohumeral rotation PROM, glenohumeral internal and external rotation isometric strength, scaption isometric strength, and 100-mm VAS pain scale and QuickDASH™ sports scores. Each participant in this repeated measures study received LSC treatment method and SC treatment method after pitching in 2 simulated baseball games. For the cryotherapy treatment, all participants had ice packs applied over anterior and posterior shoulder and elbow for 20 minutes at the end of the treatment methods. Each participant threw 3 innings of a simulated game (a total of 45 pitches) and then was randomly assigned to receive either the SC or LSC post-pitching treatment method. The participant returned to the laboratory at 24 and 48 hours after the simulated game pitching to provide follow-up

measures of glenohumeral joint strength and PROM, and complete patient-oriented measures of functional ability and pain level. Two weeks later, each participant repeated an identical bout of simulated game pitching and then was treated with the alternate recovery method, again returning to the lab for follow-up data collection at 24 and 48 hours intervals.

There are some implications and limitations for this study. The effects of LSC and SC treatments after pitching could not be compared with true control group with no treatment in this study. The effects of LSC and SC treatment need to be compared with the effects of no treatment after pitch to determine the true treatment effects.

Extra few days of data collections for each treatment were needed to determine the complete recovery time. We observed the positive treatment effects for most of variables and observe that LSC was significantly better treatment than SC treatment for the recovery after pitch in the simulated game. However, many of variables were not completely recovered to the baseline during the 48 hours of this study period except glenohumeral internal rotation PROM, glenohumeral internal rotation strength, external rotation strength, scaption strength, velocity with LSC treatment method. Future studies could design to conduct the study few more extra days to determine the complete recovery time for each treatment methods.

LSC and light shoulder exercise and stretch with no cryotherapy (LS) need to be compared to determine the cryotherapy effects. Recently some articles were published and recommend no ice or short duration of ice after activity. LS treatment method and LSC treatment method need to be compared to determine better treatment for recovery after pitching. In addition, the recommendation of the frequency and duration of the

cryotherapy after baseball pitching based on pitch counts or innings need to be determined. As a practitioner, it is hard to determine the frequency and duration of the best effects of cryotherapy based on pitch counts or innings for the best treatment effects.

This study should be conducted and compare the effects with various population such professional baseball pitchers, various level of collegiate baseball pitchers, high school baseball pitchers, adolescent pitchers. The future study may need to increase the pitching volume to induce the additional soreness or reduce the pitching volume to reduce the soreness after pitch based on the population. Three pitchers reported VAS score as less than 10 during the experience while 3 pitchers scored over 65 on VAS score.

This study showed the effects of light shoulder exercise on recovery of glenohumeral internal rotation, total glenohumeral ROM, shoulder strength, and DOMS. In the future study, the frequency, duration, and necessity of cryotherapy based on pitch counts or innings need to be determined. The ideal of volume or intensity of light shoulder exercise after baseball pitching is not sure. The different volumes of light shoulder exercises after pitching would be compared to determine the ideal exercise volume after pitching for the recovery.

Recommendations for Future Research

- The effects of LSC and SC treatment need to be compared with the effects of no treatment after pitch to determine the true treatment effects.
- Extra few days of data collections for each treatment were needed to determine the complete recovery time.
- LSC and light shoulder exercise and stretch with no cryotherapy (LS) need to be

compared to determine the effects of cryotherapy.

- Frequency, duration, and necessity of cryotherapy should be determined based on pitch counts or innings need to be determined.
- May need to increase pitching volume to induce additional soreness or decrease pitching volume to reduce the excessive soreness based on the population.
- Compare the same protocol with various populations such professional baseball pitchers, various levels of collegiate baseball pitchers, high school baseball pitchers, adolescent pitchers.
- Compare the low, medium, and high volumes of light shoulder exercises after pitching to determine the ideal exercise volume after pitching for the recovery.

APPENDIX SECTION

REVIEW OF LITERATURE

Baseball pitching places tremendous stresses on shoulder and elbow joints, and the repetitive force of throwing a baseball changes the glenohumeral joint structures and induces shoulder pathologies. Shoulder and elbow are common body parts to be injured in baseball players. The throwing motion produces the huge power and translates the force from lower body, abdominals, and back to upper extremity included shoulder and elbow.^{2,3,39,51,52} The chronic stresses placed on the shoulder and elbow during pitching induce loss of shoulder internal rotation⁴⁻⁶ and total glenohumeral range of motion⁷⁻⁹, glenohumeral internal rotation deficit (GIRD)⁷⁻¹⁰, instability of shoulder, and loss of strength of shoulder muscles¹¹⁻¹⁴. Acute alterations of range of motion and strength of glenohumeral joint after baseball pitching need to be recovered to prevent chronic change of shoulder structures and reduce the risk of shoulder injuries.

Fatigue is a primary casual factor of shoulder injuries among baseball pitchers.¹⁵ The shoulder muscles and surrounding structures have important roles to stabilize the shoulder, relying primarily on the rotator cuff muscles, glenohumeral labrum, and joint capsule to support a joint with larger humeral head and small glenoid fossa of scapula.¹⁴ Fatigue affects shoulder strength and velocity immediately after repetitive throwing.^{12,13} Weak shoulder muscles increase the risk of throwing-related injuries requiring surgical repairs.¹¹ Moreover, fatigue from number of repetitive throwing leads to losing sensorimotor control system of shoulder and entire body.¹⁵ Fatigue can affect the

sensorimotor control with a loss of proprioception that can cause a significantly different arm path while throwing a baseball.¹⁵ In other words, fatigue leads the loss of the position sense and dynamic stability of shoulder and the other joints and degenerates throwing mechanics.

Fatigue from throwing leads the failure of voluntary muscle activation, weakness of shoulder and arm muscle strength, and lowering the pitch velocity.¹² Losing muscle strength means that the players lose the support of the joint stability and increase the stress on the shoulder and elbow joints. Escamilla et al found that alternation of the throwing mechanics after 105 and 135 pitches for 7-9 innings.⁵³ Primary factor of the alternation of throwing mechanics is due to fatigue, and loss of strength and position sense from repetitive throwing. Moreover, pre-season weakness of shoulder muscles increase the risk of throwing-related injury requiring surgical intervention.¹¹

The increased external rotation ROM found among high-level pitchers is believed to be a necessary adaptation that results in improved mechanical advantage and increased pitching velocity (Burkhart, 2003; Werner, 2001). However, maladaptation of glenohumeral joint can diminish the ideal shoulder movement and increase the injury risk.⁵ Baseball pitchers need to maintain the delicate balance of the stability and mobility of shoulder for optimal performance.^{5,16,17} Optimal balance of shoulder internal rotation and external rotation ROM reduces the translation of center of humeral head rotation on the glenoid fossa of scapula.¹⁸ The balance of shoulder internal rotation and external rotation is altered by repetitive throwing in baseball pitchers, as they commonly are found to have excessive external rotation and limited internal rotation ROM.^{3,7,11-19, 29,36-40} Total glenohumeral ROM, the sum of internal and external ROM should be the same bilaterally

even in the presence of decreased internal rotation and increased external rotation ROM in the pitching arm.⁹

A Major League Baseball (MLB) season consists of 162 games for the 6 months of the regular season while the NCAA collegiate baseball season typically consists of 60 games in 4 months. Currently, most MLB teams employ a 5 pitcher starting rotation, that is, each of the pitchers has one start (game) every 5 days. In contrast, collegiate baseball starters are generally on a 7 day-rotation. High demand relievers are throwing every other day or possible 2 or 3 days in a row. Moreover, the pitching frequency would increase during the championship games. Baseball pitchers need to recover from the pitch and be ready for the next game as quick as possible for the performance and prevention of injuries. In 2014 season, several major league organizations have been considered 6 man rotations as the pitchers who needed to take a Tommy John surgery due to ulnar collateral ligament tear on elbow increased and this has been a serious problem. The failure to recover from the pitch for the next pitching day will decrease performance and be the cause of injury. The recovery methods after baseball pitching will be very important to allow the pitchers to be ready for the next game and prevent shoulder and elbow injuries.

As a clinical finding, a lot of baseball players have mentioned that the recovery methods included light shoulder exercise and shoulder stretch after pitching is effective to maintain the shoulder strength, stability and ROM, and reduce the delayed onset muscle soreness (DOMS) and stiffness. However, the effectiveness of light shoulder exercise program for recovery after baseball pitching is unclear.

In this literature review, I will provide the influence of the throwing on the

shoulder strength and ROM, and the interventions for the recovery from baseball pitching.

Days of Rest and Performance

Managers, coaches, and athletic trainers have suggested limiting number of pitches and taking certain number of days of rest to prevent overuse and fatigue that relates to injuries. Bradbury found that the pitching performance included decreasing strike outs per 9 innings, increasing home runs per 9 innings, walks per 9 innings, and earned run average was affected by the number of throwing in the previous game even though there was small impact.¹ Additional days of rest beyond the normal after 3 days of rest did not show significant improvement of the performance.¹ Potteiger et al found that muscle damage that indicated by increasing creatine kinase levels returned to baseline after 3 days of rest from 100 pitches in simulated game.⁵⁴

Biomechanics of Baseball Pitching

The throwing motion produces 67 N-m (6.8 kg-m) of internal rotation torque, 310 N (31.6 kg, 69.7 lb) of anterior force on shoulder, and 64 N-m (6.5 kg-m) elbow varus torque at maximum external rotation in late cocking phase and 400 N (40.8 kg, 89.9 lb) of posterior force, 1,090 N (111.2 kg, 245.2 lb) of compressive force, and 97 N-m of horizontal abduction torque on shoulder after ball release in acceleration phase.^{2,3} Maximum internal rotation instantaneous velocity has been measured at 6,100 to 7,900 degrees per second in collegiate and professional baseball pitchers, respectively.^{2,3} Shoulder joint can rotate internally 16.9-21.9 times per second with this maximum internal rotation instantaneous velocity. This tremendous stress on the shoulder leads several shoulder pathologies.

In addition, glenohumeral internal rotation deficit (GIRD) and loss of total glenohumeral ROM alter the kinematics of shoulder.^{10,23,24} The center of rotation of the humerus translates anterosuperiorly during shoulder forward flexion²³ and posterosuperiorly during external rotation and arm cocking phase.^{10,24}

Shoulder Pathologies

Shoulder impingement syndrome is called as subacromial impingement and classified as primary and secondary impingement syndrome.⁵⁵ Primary impingement would be caused by the mechanical impairment.⁵⁶ Secondary impingement would be caused by the shoulder instability, scapulothoracic weakness, and posterior shoulder tightness. Some studies described that the loss of shoulder internal rotation and horizontal adduction ROM increase the risk of shoulder impingement syndrome. The shoulder impingement patients with posterior capsule tightness showed a significant correlation to the loss of internal rotation ROM.⁵⁵ GIRD with loss of internal rotation greater than $19.7^{\circ} \pm 12.8^{\circ}$ had a significant risk of internal impingement due to posterior capsule and rotator cuff musculature adaptation while the throwers without impingement had average 11.1° of GIRD.⁷ The average change in posterior capsule tightness of the baseball players with impingement was 4.2 cm compared to uninvolved shoulder.⁷ No significant differences were observed internal rotation gain in throwers with pathologic internal impingement.^{7,55}

Baseball pitchers with GIRD and loss of total ROM have higher risk of glenohumeral labrum tear and superior labrum anterior and posterior (SLAP) lesions. GIRD and loss of ROM alters the kinematics of shoulder and the center of rotation of the humerus shifts anterosuperiorly during shoulder forward flexion²³ and posterosuperiorly during external rotation and arm cocking.^{7,10,21,25} This abnormal humeral shift on the

glenoid fossa will be the cause of labrum tear.^{7,10,21,25} Forty-four baseball pitchers with type II SLAP lesions were found to have a loss of shoulder internal rotation of 25° or more, which was defined by the authors as GIRD.⁵⁷ All of type II superior labrum from anterior to posterior (SLAP) lesions had a severe loss of internal rotation in throwing arm.¹⁰

Moreover, pathologic GIRD may be associated with elbow valgus instability.⁷ Throwers with ulnar collateral ligament insufficiency of elbow had an average GIRD of 28.5° and asymptomatic throwers showed an average GIRD of 12.7°.⁵⁸ Abnormal humeral movement due to GIRD and loss of total ROM increase the risk of elbow injury.⁵⁸

Glenohumeral Strength

The shoulder muscles have an important role as glenohumeral joint stabilizers.¹⁴ Glenohumeral joint highly relies on rotator cuff muscles and surrounding muscles to stabilize and support unstable joint.¹⁴ Fatigue affects shoulder strength immediately after repetitive throwing.^{12,13} The deceleration phase of throwing is the most stressful period for rotator cuff muscles due to the eccentric muscle activity to slow down the throwing arm.⁵⁹ Repetitive over stress on rotator cuff muscles from eccentric muscle activity lead a muscle tear, inflammation, and muscle weakness.^{3,14,60} Weak glenohumeral joint stabilize muscles are associate with throwing related injuries requiring surgical repairs.^{11,46,47} Majority of studies shows the ratio of external rotation to internal rotation strength is between 0.60 to 0.80.^{52,59,62-69,}

Failure of voluntary infraspinatus muscle activation is the sign of external rotation muscle weakness due to fatigue from throwing.¹² Gandhi et al (2012) reported significant

infraspinatus weakness (voluntary activation; 96% → 89%, $P = .01$) due to fatigue after baseball pitching in the game. The subjects threw average 87 pitches (range; 75-90 pitches) with fastball (67%), curve balls (25%), and change up (8%). There were no differences between throwing and non-throwing shoulder strength and voluntary activation of infraspinatus before the game ($P=.27$).¹² However, voluntary activation of the muscle in throwing shoulder was significantly lower after the game ($P = .01$) with lowering the pitch velocity (mean; 65 mph → 63 mph, $P = .01$).¹²

Furthermore, significant loss of arm strength has been seen after pitching approximately 7 innings and throwing 100 pitches.¹³ College and minor league baseball starting pitchers ($n = 13$) participated the study of Mullaney.¹³ After numerous number of pitches (7 ± 2 innings, 99 ± 29 pitches) loss of 15% shoulder flexion, 12% abduction, 6% abduction on scapular plane with internal rotation, 18% internal rotation, 11% external rotation, 11% adduction strength, and 4% grip strength were observed compared with strength measurements 1 to 2 days before the starting game.¹³ This study showed that muscle fatigue were observed primarily in the shoulder muscle and minimally in the scapular muscle included lower trapezius, middle trapezius, and rhomboids.¹³ Internal rotator muscles were highly demand for pitching and relate to fatigue.¹³ Supraspinatus strength tests showed minimal fatigue.¹³ External rotators strength change were not statistically significant.¹³ Losing muscle strength means that the players lose the support of the joint stability and increase the stress on the shoulder and elbow joints.

Byram et al. concluded that preseason weakness of external rotators and supraspinatus increase the risk of throwing-related injury requiring surgical intervention. Major and minor league baseball pitchers ($n = 144$) participated during the 5 years (2001-

2005) of study period.¹¹ Preseason strength testing of prone internal rotation, prone external rotation, seated external rotation⁴, supraspinatus was performed in the spring training (February and March)¹¹. Three trials were performed and calculated the average.³⁵ The relationship between the weakness of prone external rotation (P = .003) and seated external rotation (P = .048) and supraspinatus (P = .006) in preseason and throwing related injuries required surgical repair was statistically significant.¹¹ The study revealed that baseball pitching highly demands on internal rotators.¹¹

Measurement Method

Shoulder flexion, abduction, abduction on scapular plane with internal rotation , internal rotation, external rotation, adduction, lower trapezius, middle trapezius, and rhomboids strength and grip strength were tested with the hand-held dynamometry to measure shoulder and scapular strength.¹³ The several studies investigated the validity and reliability of hand-held dynamometers.⁶¹⁻⁶⁴ In addition, serratus anterior muscle strength test was performed by Donatelli et al.⁴⁴ Break tests were used for all measurements and handheld dynamometer was positioned over the distal forearm and proximal to the radiocarpal joint.¹³ The strength tests were performed twice¹³ or three times¹¹ and the average was calculated.

The subjects were sitting and the testing arm was positioned at 90° flexion for the shoulder flexion test and 90° abduction for the shoulder abduction strength test.¹³ Subjects were instructed to hold the chair to stabilize the torso with the other hand.¹³ Supraspinatus strength was measured with the arm position; 90° shoulder abduction, 30°^{13,44} or 45°¹¹ horizontal adduction and fully shoulder internal rotation^{13,44} or forearm neutral¹¹. This is the position of scaption that activate supraspinatus muscle fully.⁶⁵

Shoulder internal rotation and external rotation were measured in the supine^{13,44} and prone and seated position¹¹. The extremity was positioned at 90° shoulder abduction and 90° elbow flexion, and the forearm was placed perpendicular to the floor.^{11,13,44} Players were positioned on the examination table with 0° of shoulder abduction, 90° of elbow flexion, thumb up position with sitting against the wall for SER test.¹¹ The handheld dynamometer was placed palmar side for the internal rotation test and dorsal side for the external rotation strength test.^{13,44} The participants were positioned prone with 0° abduction and slight extension for the adduction strength test. Patients were instructed to adduct and slightly flex the arm during the measurement.¹³ Lower trapezius and middle trapezius strength test were performed in the prone position.^{13,44} The testing arm was positioned 145° of shoulder abduction and thumb up for the lower trapezius testing and 90° shoulder abduction and thumb up for the middle trapezius strength test.^{13,44} Rhomboid was tested with shoulder horizontal abduction and maximal shoulder internal rotation.^{3,34} Patient was instructed to adduct scapula.^{13,58} Serratus anterior strength was measured in the supine position with 90° shoulder flexion and full elbow extension.⁴⁴ The hand-held dynamometer was placed over the fist of the testing arm.⁴⁴

Range of Motion (ROM)

Shoulder Internal Rotation and External Rotation

Baseball players need to maintain the delicate balance of the stability and mobility of shoulder for optimal performance.^{16,17} The balance of shoulder internal rotation and external rotation is necessary for effective pitching in baseball pitchers.⁵ Most baseball players have shoulder ROM differences between their throwing arm and non-throwing arm due to repetitive throwing.^{3,7,11-19, 29,36-40} An excessive external rotation and limited internal rotation at 90° abduction of throwing shoulder is common adaptation for the baseball players.^{7,11-19 29,40} The posterior inferior glenohumeral ligament was tighten and thickened in throwers with GIRD as arthroscopic findings.¹⁰ Pitchers have a greater risk for shoulder injury than position players when the players have the same level of GIRD or loss of shoulder internal rotation ROM.⁸ GIRD is defined as the loss in degrees of glenohumeral internal rotation of the throwing shoulder compared with the non-throwing shoulder.¹⁰ Burkhart et al. suggested that GIRD is due to posterior capsular tightness.¹⁰

Acute Adaptation

Reinold and Kibler both observed that there was an acute loss of shoulder internal rotation and total glenohumeral ROM immediately after pitching.^{5,6} Repetitive eccentric external rotation muscle activity have decreased significantly shoulder and elbow ROM immediately after pitching on mound for 50 to 60 pitches at full intensity⁶ The study of Reinold showed a decrease in passive shoulder internal rotation (-9.5°), total motion (-10.7°), and elbow extension (-3.2°) after baseball pitching and it lasted 24 hours after the pitching.⁶ The causes of stiffness of motions are the inflammation and soft tissue edema in the perimysial and/or epimysial connective tissue elements from an eccentric muscle

contraction⁴ The pitching before the recovery from the muscle damage and loss of shoulder and elbow ROM will be the cause of injuries.

Kibler et al. have investigated the shoulder internal rotation, external rotation, and total glenohumeral ROM after throwing in the game. Starting pitchers (n = 22) and relievers (n = 23) from professional baseball team (22.3 ± 2.6 years; height, 187.9 ± 6.2 cm; weight, 90.4 ± 9.1 kg) participated during 2009 spring training. Shoulder internal rotation and external rotation and total glenohumeral ROM was measured before warm up or stretching, immediately after, 24, 48, and 72 hours after throwing⁵ Starting pitchers threw maximum of 3 innings and 64 pitches, relievers threw maximum of 2 innings and 41 pitches.⁵ Kibler et al. concluded that the loss of internal rotation ROM after pitching (mean = -7°) did not return to the baseline even after 72 hours of recovery time.⁵

On the other hand, Mullaney did not find the significant difference of internal rotation and external rotation ROM before and after pitches.¹³ The collegiate baseball pitchers showed loss of $2.7^\circ \pm 9.5^\circ$ of internal rotation ROM after baseball pitching (7 ± 2 innings, 99 ± 29 pitches) the game.¹³ It was not significant loss of ROM in the study.

Chronic Adaptation

GIRD or loss of throwing shoulder internal rotation compared with non-throwing arm is highly related to shoulder injuries in baseball players.¹¹⁻¹⁹ Injured professional pitchers had mean $10.1^\circ \pm 9.0^\circ$ of GIRD in throwing arm and a mean internal rotation loss in position players was $13.5^\circ \pm 8.8^\circ$.⁶⁸ Pitchers with no past shoulder injury had mean $3.1^\circ \pm 11.2^\circ$ of GIRD and position players with no past shoulder injury had mean $4.2^\circ \pm 13.8^\circ$ of IR loss.⁶⁸

Burkhart, Borsa, and Shanley mentioned that greater than 25° loss of internal

rotation in throwing shoulder compared with non-throwing shoulder is a great risk of shoulder injuries.^{8,10,50} All of type II superior labrum from anterior to posterior (SLAP) lesions had a severe loss of internal rotation in throwing arm.^{8,10,50} GIRD with greater than $19.7^\circ \pm 12.8^\circ$ loss of internal rotation had a risk of internal impingement.⁷ Burkhart and Wilk also mentioned the risk of higher degree of GIRD.^{9,10} Pitchers with greater than 20° of GIRD showed a higher risk of shoulder injuries compared with the pitchers with less than 20° of GIRD.^{9,10}

Shanley had several interesting findings from their research with 246 high school baseball players. There were 4 to 5 times greater risk of upper extremity injury when baseball players had a greater than 25° loss of throwing shoulder internal rotation compared with the players who had a less than 25° loss of internal rotation.⁸ The risk of throwing shoulder injury was increased by 2 to 3 times with 20° to 25° GIRD and 1.5 to 2 times with 10° to 20° GIRD.⁸ Injured pitchers with a greater than 25° loss of internal rotation had a 10 times greater risk of upper extremity injury compared with the pitcher with less than 25° loss of range of motion (ROM).⁸

Measurement Method

The measurement was performed twice for each and calculated the average in the study of Shanley et al.⁸ Two examiners measured the ROM, one to position the shoulder and arm of subjects and another to position and read the goniometer.^{8,42} The subjects were supine and positioned one of the arms at 90° of abduction and 10° of horizontal adduction in the plane of scapular with a small towel roll.^{8,42} The examiner stabilized the scapular with one hand with the table and external rotate or internal rotate the arm holding wrist with the other hand passively.^{8,42} The extremity was held at the full ROM

with full capsular or bony end feel was observed.⁴² The measurement was performed bilaterally.^{8,42} The extremity was held when the subjects started lifting humeral head. The examiner did not stabilize the humeral head to avoid the alternation of shoulder arthrokinematics.⁴² The other examiner aligned a standard goniometer with a bubble inclinometer; fulcrum over the olecranon process, stationary arm perpendicular to the floor, and moving arm along the ulnar to the ulnar styloid process.⁴⁴ All measurements were performed within 30min of pitching.⁴²

Total Rotation (Internal Rotation + External Rotation)

Background

Total glenohumeral ROM, the sum of internal and external ROM should be the same bilaterally even in the presence of decreased internal rotation and increased external rotation ROM in the pitching arm.⁹ Total rotation of throwing shoulder ROM differences compared with non-throwing shoulder related to shoulder injuries.^{8,9} Wilk showed that pitchers with total rotation difference greater than 5° had 2.5 times more chance to be injured.⁹ The injured pitcher had an average 183.7° total rotation on the throwing arm and 187.7° on the non-throwing arm.⁹ Shanley also mentioned that baseball players with lower total rotation were more likely to be injured.⁸ The injured baseball players had a mean 4.7° deficit of total throwing shoulder rotation compared with non-throwing arm.⁸ A 5° asymmetry in TROM has been shown to be predictive of increased injury risk.⁸ Myer et al (2006) found out that the average of total rotation was 172.1° on injured baseball players and 180.1° on uninjured baseball players.⁷ Kibler has identified the decrease of total motion after an acute throwing.⁵

Measurement Method

Total motion was calculated the sum of internal rotation and external rotation.⁶⁹

Horizontal Adduction

Background

Posterior capsule tightness of shoulder will be the possible cause of the loss of shoulder internal rotation.¹⁹ Tightness of posterior capsule interferes with the proper throwing mechanics and can lead to the subacromial impingement, rotator cuff injuries, and glenohumeral joint capsule tears.²⁰ Posterior shoulder tightness is commonly seen among the baseball pitchers. Division I intercollegiate baseball pitchers ($n = 23$, 20 ± 1.2 years) with no history of significant shoulder injury showed greater posterior shoulder tightness (mean: 12.0 cm) significantly than non-impaired healthy subjects (25 men, 24 women, 30 ± 8.9 years).⁵⁷ The baseball pitcher showed an average 7.4 cm horizontal adduction loss of motion on dominant shoulder compared to non-dominant.⁵⁷

The posterior shoulder tightness more than 2.2 cm is statistically significant.⁵¹ Patients with unilateral shoulder impingement showed an increase in 2.62 cm on non-dominant or 6.44 cm on dominant shoulder.⁵⁷ However, it is difficult to determine how much of posterior tightness indicate clinically significant.⁵¹ Eleven baseball players with shoulder impingement (22.1 ± 3.5 years) and 11 baseball players without shoulder impingement (21.2 ± 1.7 years) from college and semi-professional baseball team participated in the study of Myer et al.⁷ The patients with pathologic internal impingement showed the average of 4.2 cm posterior shoulder tightness compared with uninvolved shoulder.⁷ Injured high school baseball player showed the loss of average 4.8° shoulder horizontal adduction ROM compared with non-throwing arm and 7.1° less horizontal adduction compared with non-injured high school baseball player.⁸

Approximately every 4.0-4.7° of loss of internal rotation indicates 1 cm of posterior shoulder tightness.^{7,19,46,57} Posterior shoulder tightness is correlated to the loss of shoulder internal rotation significantly in the patients with shoulder impingement.⁵⁷

Measurement Method

Tyler described the side-lying horizontal adduction measurement method for posterior shoulder tightness.^{19,57} The subjects were instructed side-lying position with approximately 90° of knee and hip flexion on the training table.^{19,57} Bilateral acromion processes was aligned perpendicular to the floor and the spine was in the neutral position; no flexion, extension, and rotation.^{19,57} The starting arm position was 90° abduction, 0° internal rotation and 0° external rotation, and scapula is retracted with holding distal to the epicondyles of elbow and lateral border of scapula.^{19,57} The examiner horizontally adducted the humerus passively.^{19,57} The measurement was performed using a 60 cm carpenter's square to measure the distance between the table and medial epicondyle.^{19,57}

Myers et al. investigated another way to measure the posterior shoulder tightness and determined the measurement in supine position is effective method to measure posterior shoulder tightness.⁴⁶ The subjects were positioned supine with the scapula retracted on the table.^{45,46} The examiner stabilized the lateral border of the scapula with one hand at 90° shoulder abduction to limit scapular motions of protraction, and rotation.^{45,46} The starting position was 90° horizontal adduction and the examiner passively moved the extremity to the full horizontal adduction⁸ ROM with holding proximal forearm and distal to the elbow.^{45,46} The other examiner aligned digital inclinometer⁴⁵ or the standard goniometer⁴⁶; fulcrum over the center of glenohumeral joint, stationary arm along the mid line of humerus, and moving arm parallel to the

floor.^{45,46}

Velocity and Accuracy

Gandhi et al. reported significant lowering the pitch velocity (mean; 65 mph → 63 mph, $P = .01$) with infraspinatus weakness (voluntary activation; 96% → 89%, $P = .01$) due to fatigue after average 87 baseball pitches in the game.¹² The velocity was recorded using a radar gun positioned behind the target net.¹²

Recovery Methods

Several recovery methods included light cardiovascular exercise³⁴, light shoulder exercise, shoulder and forearm stretch, and cryotherapy^{34,36,38} are commonly used as a recovery and maintenance methods for baseball pitchers after pitching in the game, bullpen, and simulated game.

Shoulder Stretch

Background

GIRD can be relieved with regular internal rotation stretching program.³⁹ In the study of Lintner, 85 professional pitchers were participated and divided into 2 groups; 3 or more years of stretching group (group 1) and less than 3 years of stretching group (group 2).³⁹ The passive shoulder stretching technique of Houston Astros organization was used in the study.³⁹ The stretch was included (1) supine shoulder extension with elbow extension: biceps long head, superior labrum stretch (2) supine shoulder extension with elbow flexion: anterior capsule stretch (3) 90/90 external rotation: shoulder internal rotators stretch (4) 90/90 internal rotation without holding humeral head: scapula-

thoracic musculature stretch (5) 90/90 internal rotation with holding humeral head:
posterior glenohumeral soft tissues stretch (6) Cross-over stretch without holding scapula:
posterior scapula-thoracic musculature stretch (7) Cross-over stretch with holding
scapula: posterior glenohumeral musculature and posterior capsule stretch (8) Prone
internal rotation hand on back with scapular winging: posterior scapula-thoracic
musculature stretch (9) Stretch 8 with preventing scapular winging: posterior
glenohumeral soft tissues stretch.³⁹ The group with over 3 years of stretching showed
greater internal rotation (74.3°) than the group 2 (54.3°).³⁹ GIRD in the group 1 (6.22°)
was significantly less than group 2 (18.3°).³⁹

The cross-body stretch improved significant increase the IR of the subjects with
GIRD.⁴¹ The shoulder internal rotation of the cross-body stretching group (mean±SD,
20.0°±12.0°) increased significantly in 4 weeks study.⁴¹ Manske also found the
significant shoulder internal rotation improvement (mean=15.4°) with the cross-body
stretching technique in 4 weeks study.⁴⁰ The range of motion (ROM) of shoulder internal
rotation decreased (mean=3.6°) after 4 weeks of post intervention.⁴⁰

Cryotherapy

Background

Baseball pitchers repeat micro trauma to shoulder and elbow from each baseball
pitching. Cryotherapy is the most common treatment for acute musculoskeletal injuries at
the athletic training settings.³⁶ There are different types of cryotherapy including an
application of crushed ice, cold water immersion, gel packs, and cryo-cuff.⁷⁰ Application
of ice is the most common cryotherapy at the clinical site of the sports to reduce muscle
damage after the activity.³⁷ There are number of positive effects to the acute injuries from

the cryotherapy treatment. Cold therapy reduces the blood flow, metabolic rate, hemorrhage, and edema formation.³⁸ Secondary tissue death and muscular damage can be prevented by decreasing the demand of oxygen to the muscles so that the recovery time of tissue damage from the activity can be reduced.³⁵ Application of cryotherapy after the exercises has some advantages to reduce muscle tension, circulation, and inflammation by the effects of anesthesia, muscle spasm reduction, muscle relaxation.³⁵

Passive and Active Recovery

Background

The primary cause of delayed onset muscle soreness (DOMS) is large quantities of eccentric muscle activity that induce muscle damage.²⁶ The muscle actions of posterior rotator cuff muscles and biceps brachii during throwing motion of baseball pitcher are considered as eccentric muscle activity that commonly induce posterior shoulder soreness and tightness after pitching of baseball. The symptoms of DOMS are tenderness to palpate and/or movement, pain, discomfort, decreasing flexibility, maximum force production, and performance.^{26,27} Reducing DOMS is one of the key components of the recovery from strenuous activity to maintain optimal performance.

The Passive recovery is a rest without activity in sitting, lying down quietly, and/or stretching.²⁸ Fifteen to twenty-five minutes of passive recovery has a effects to return the decreased pH levels after moderate intensity exercise.²⁹ Passive recovery also maintains the increased blood lactate concentrations.^{30,31} Active recovery is involved submaximal cardiovascular exercise that increases the blood flow to facilitate removal of the blood lactate.^{30,32} Lowering blood lactate concentrations rates after the strenuous activities were better with active recovery than passive recovery.³³ Most effective

clearance of blood lactate was at the intensity of close to the lactate threshold that is the point starting increase the blood lactate concentration.³³ However, the effectiveness of light shoulder exercise for recovery is unsure.

Light Shoulder Exercise

Shoulder stretch and cryotherapy^{31,34} are commonly used as a recovery and maintenance methods for baseball pitchers after pitching in the game, simulated game, and bullpen. Light shoulder exercises are also commonly used for maintenance of shoulder after the baseball pitching. As a clinical finding, baseball pitchers have mentioned that the recovery method with light shoulder exercise, stretch, and ice after pitching is effective to maintain the shoulder strength, stability and ROM, and reduce the soreness and stiffness for the day after pitch. However, there are very limited studies that verify the light shoulder exercises are effective or not effective recovery tools. The effectiveness of light shoulder exercise program for recovery after baseball pitching is unclear.

There is an article that examined the effectiveness of light shoulder exercise as a recovery method after baseball pitching. In the study of Yanagisawa et al (2003), the effectiveness of light shoulder exercise was examined. Yanagisawa et al (2003) compared 4 recovery methods; the control (CON), ice treatment (IT) for 20 min, light shoulder exercise with upper body cycle for 20 min and ice treatment with LSE (ILSE) on shoulder ROM and muscle cross-sectional area (mCSA) after baseball pitching. Seven highly skilled amateur baseball pitchers (23.0 ± 1.29 years) were tested.³⁴ Subjects have no significant history of shoulder and elbow injuries.³⁴ Yanagisawa et al. concluded that ILSE was more effective recovery methods to reduce post-pitching edema and shoulder

tightness than the other.³⁴

The isotonic shoulder exercises are commonly used for the rehabilitation and prevention program. Reinold et al. suggested to use the following shoulder exercises included shoulder abduction, standing full can, prone full can, prone horizontal abduction at 90° abduction with external rotation, prone extension with external rotation, prone external rotation at 90° abduction, prone row, and side-lying external rotation to strengthen and stabilize the shoulder joint for the baseball players.^{6,42} Diagonal internal rotation and external rotation, external rotation at 0° abduction, internal rotation at 0° abduction, and serratus punch 120° would be performed with manual resistance.^{6,42}

Conclusion

Altering of shoulder strength and ROM relates to shoulder injuries for baseball pitchers. The acute loss of strength of shoulder muscles and shoulder ROM need to be recovered before the baseball pitchers throw for the next game day to reduce the risk of shoulder injuries. The light shoulder exercise program has been used as a recovery and maintenance method after baseball pitches. However, the effectiveness of light shoulder exercise program for recovery after baseball pitching is unclear. Sports medicine clinicians need to know the effectiveness of light shoulder exercise and the effectiveness needs to be verified to use the method as a recovery and maintenance method after the baseball pitching.

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