Throughout the various levels of baseball competition, pitchers often suffer season-ending or career-ending injuries. Significant improvements have been made in the treatment and rehabilitation of these injuries, with a lesser amount of attention given to injury prevention. The purpose of this study was to determine the effectiveness of an in-season shoulder and scapular muscle strengthening program in the maintenance of the throwing velocity among high school baseball pitchers. Twenty-four apparently healthy high school baseball pitchers at four schools volunteered to participate in this study; each school was randomly assigned to either the treatment group or the control group. The treatment group pitchers (n = 12) engaged in a progressive resistance exercise (PRE) strengthening program using Thera-Band® surgical tubing for six weeks, while the control group pitchers (n = 12) did no additional strengthening or stretching activities beyond their normal baseball training. Each subject’s pitching velocity was measured using a JUGS® radar gun at the beginning of and following the six-week study period. Pretest and posttest concentric and eccentric muscular strength and power at 60 and 240
deg/sec were measured for the internal and external rotators of the shoulder using a KinCom 500H isokinetic dynamometer. Results of one-way ANOVAs indicated no significant differences between the groups on any of the experimental parameters at the beginning of the study (p > 0.05). Over the course of the baseball season, pitchers in the treatment group increased their throwing velocity an average of 6.2 mph compared to an average increase of 1.5 mph in the control group (p < 0.001). Group x Time interaction effects (p < 0.03) for 7 of 8 isokinetic peak torque measures indicated significant improvements in shoulder strength in the treatment group at the posttest evaluation. No time-loss shoulder or elbow injuries occurred in the treatment group during the six-week PRE program. Our results suggest that participation in an in-season PRE program of surgical tubing exercises for the shoulder was safe and successful, not only in maintaining, but significantly improving pitching velocity and the strength of the shoulder internal and external rotators among high school baseball pitchers. Our findings support the use of this low cost surgical tubing PRE program as a means to improve the throwing velocity of high school baseball pitchers.
The Effectiveness of a Surgical Tubing Strengthening Program in the Maintenance of Performance Among High School Pitchers.

by

Neeraj D. Baheti

A THESIS

Submitted to

Oregon State University

in partial fulfillment of the requirements for the degree of

Master of Science

Presented November 21, 2000
Commencement June, 2001

APPROVED:

Redacted for privacy

[Signature]

Major Professor, representing Human Performance

Redacted for privacy

Chair of Department of Exercise and Sport Science

Redacted for privacy

Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Neeraj D. Baheti, Author
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I want to thank the College of Health and Human Performance for providing funding (Dean’s Scholarship) to purchase equipment used in this research.

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Finally, the completion of this Master of Science is a result of an enormous support of my family and my friends, both in the United States and in India.
CONTRIBUTION OF AUTHORS

Dr. Rod A. Harter was involved in the conceptualization and development of the research questions, experimental design, analysis, and writing of the manuscript.
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DEDICATION

This work of Master’s thesis, which is a milestone in my life is dedicated to

my papa and mummy.

Without their immense support and encouragement,

I would not be able to come this far.
The Effectiveness of a Surgical Tubing Strengthening Program in the Maintenance of Performance Among High School Pitchers

CHAPTER 1

INTRODUCTION

Throughout the various levels of baseball competition, pitchers frequently suffer season-ending or career-ending injuries. In fact nearly every pitcher sustains a major injury at some point in his career.\textsuperscript{1} According to NCAA intercollegiate baseball injury surveillance system data for 1998 and 1999, the shoulder was the most frequently injured of all the body parts, accounting for 21\% and 14\% of all the injuries, respectively. Throwing or pitching was responsible for greater than one-third of practice injuries and about one-fifth of game injuries.\textsuperscript{29,30} According to NCAA injury surveillance system data, the overall injury rate for baseball (all injuries to all players) was 5.8 per 1000 athletic exposures for 1998 and 6.1 per 1000 athletic exposures for 1999.\textsuperscript{29,30} In 1998, 38\% of all injuries restricted participation of the athlete for seven days or more.\textsuperscript{30} The frequency of shoulder injuries is not particularly surprising, considering the forces and velocities that are developed during the pitching action.\textsuperscript{26}

Much of the existing baseball research has focused on the biomechanics of throwing, clinical management of injuries, and rehabilitation techniques, with a lesser amount of attention given to injury prevention.\textsuperscript{4,14,15,26,37,38,44,46} Time and effort spent in developing and implementing injury prevention programs in baseball can be highly beneficial and contribute to the success and longevity of the player's career. Andrews and Fleisig\textsuperscript{1} contend that the steps for preventing pitching injuries must be implemented at
the youth level because not only there are significant numbers of pitching injuries in youth baseball, but also the measures implemented in youth baseball may help reduce injuries at higher playing levels.

Among athletes participating in overhead sports activities, microtrauma is more common than macrotrauma.\textsuperscript{5,45} One of the most common injuries among the pitchers is impingement of the rotator cuff muscles in the shoulder. Primary impingement is typically caused by a crowding or stenosis of the subacromial space due to hooked acromion, bicipital tendonitis, calcific deposits in subacromial bursa, or subacromial bursitis, among other causes.\textsuperscript{19} Secondary impingement is usually seen in younger athletes with overhead activities and is usually associated with symptomatic glenohumeral instability, which may be either traumatic or atraumatic.\textsuperscript{45} Due to the repeated overhead activity, the anterior band of the inferior glenohumeral ligament complex (IGHLC), which acts to support the humeral head, undergoes a gradual creep deformation that can result in subluxation of the humeral head.\textsuperscript{13,34}

Since all the rotator cuff muscles originate on the scapula and insert into the humerus, the scapula must provide a strong base for the rotator cuff muscles to act. The primary scapular stabilizers, e.g., serratus anterior, rhomboids, trapezius, play a very important role in the scapulohumeral rhythm, and in positioning the glenoid for articulation with the humeral head.\textsuperscript{20} With the repeated overhead activity by the athletes such as baseball pitchers, the scapular stabilizers tend to become weak and fatigued.\textsuperscript{5} This weakness and fatigue may be compounded by presence of injured rotator cuff muscles that are unable to guide the humeral head during overhead activities.\textsuperscript{28}
The anterior chest wall muscles are larger in physiologic cross-sectional area than the posterior chest wall muscles; this natural imbalance causes the scapula to protract and glenoid fossa to antevert. Glenoid anteversion reduces the bony restraint to anterior humeral translation, leading to a subtle anterior instability. If a stretch weakness is present among the scapular stabilizers, the acromion tends to be depressed, which in turn reduces the subacromial space and predisposes the rotator cuff muscles to impingement. This sequence of events commonly leads to a condition of abnormal kinematics termed as scapular dyskinesis and can predispose the athlete to subacromial impingement, glenohumeral instability, and dislocation of the shoulder joint.

The normal action of infraspinatus, teres minor, and the subscapularis muscles is to pull the humerus downward and inward into the glenoid fossa during glenohumeral joint abduction and flexion. In pitchers with an abnormal throwing kinematics, these muscles are injured and thus become weak, resulting in reduced opposition to the deltoid muscle’s upward pull on the humerus. This change results in a superior translation of the humeral head, eventually causing impingement of the rotator cuff between the acromion process and the head of the humerus. Thus, it is important to preserve the normal balance between the strength of scapular stabilizers and rotator cuff muscles for maintaining the normal coordination and rhythm between the scapula and humerus and prevent the impingement syndrome.

In baseball, pitching is one of the most important factors in determining whether a team will win or lose. A talented pitcher can win numerous games for his team at all levels of play. According to Shenk, velocity of pitching is generally considered the single most important factor to success at higher levels of play in baseball, even though
other factors such as accuracy, control, and movement of the ball on all types of pitches are also high priorities. There is no consensus regarding which factor affects velocity the most. Brown et al. and DeRenne et al. both reported a positive relationship between the strength of the internal and external rotator muscles of the pitcher's shoulder and throwing velocity. DeRenne found a linear relationship between increased strength of shoulder musculature and increased throwing velocity, and concluded that the shoulder musculature plays the single most important role in pitching velocity.

Progressive resistance exercises and strength training have been accepted for all aspects of baseball training and conditioning. Shenk examined the effects of weight training and surgical tubing exercises in NCAA Division I pitchers and found significant improvement in the pitching velocity of the treatment group compared to the control group, but no statistically significant differences in the strength variables between the two groups at the conclusion of the study. To our knowledge, no one has evaluated the effectiveness of a progressive resistance exercise (PRE) program using surgical tubing to strengthen the rotator cuff and scapular muscles in high school baseball pitchers in effort to prevent the injuries to these muscles and to maintain throwing velocity and performance throughout the season.

**Statement of the Problem**

The number of athletes participating in baseball at middle school and high school levels is much greater than those performing at the top professional level. However, the degree of health care, facilities and financial support available to the athletes at the professional level is far superior to that provided at the middle school or high school
levels. There remains a significant need for low-cost injury prevention programs and intervention strategies.

The purpose of this study was to determine the effectiveness of a specific scapular and shoulder muscle strengthening program using surgical tubing in the maintenance of pitching performance, i.e., pitching velocity, and improving shoulder muscular strength among high school baseball pitchers.

Chapter Two consists of a manuscript entitled, “In-Season Surgical Tubing Strengthening Program Improves Throwing Velocity Among High School Pitchers”, and will be submitted for publication in the *American Journal of Sports Medicine*.

**Specific Aims and Hypotheses**

Thirty apparently healthy high school baseball pitchers were recruited to participate in this study, and were assigned to either the treatment group or the control group. The treatment group engaged in a six-week in-season strengthening program consisting of six shoulder exercises using surgical tubing of varying resistances.

**Specific Aim # 1**

To determine if a surgical tubing strengthening program will be effective in maintaining or improving peak muscle torque of shoulder internal and external rotators in the treatment group compared to the control group.

**Hypothesis # 1**

Participation in the strengthening program will maintain or increase peak concentric and eccentric muscle torques of shoulder internal and external rotators of the treatment group of pitchers over the season as measured by a KinCom 500-H isokinetic dynamometer.
H_0: \mu_{post} - \mu_{pre} < 0

H_1: \mu_{post} - \mu_{pre} \geq 0

Where: \mu is the mean of peak muscle torques of the subjects, pre is pretest, and post is posttest.

Hypothesis # 2

There will be a decrease in the peak concentric and eccentric muscle torques of shoulder internal and external rotators of the control group of pitchers over the season as measured by a KinCom 500-H isokinetic dynamometer.

H_0: \mu_{post} - \mu_{pre} \geq 0

H_1: \mu_{post} - \mu_{pre} < 0

Where: \mu is the mean of peak muscle torques of the subjects, pre is pretest, and post is posttest.

Hypothesis # 3

There will be a significant difference (p< 0.05) in the change in the peak concentric and eccentric muscle torques of shoulder internal and external rotators of the treatment group compared to that of control group.

H_0: (\mu_{post} - \mu_{pre})_T - (\mu_{post} - \mu_{pre})_C = 0

H_1: (\mu_{post} - \mu_{pre})_T - (\mu_{post} - \mu_{pre})_C \neq 0

Where: \mu is the mean of peak muscle torques of the subjects, pre is pretest, and post is posttest.
Specific Aim #2

The second specific aim of this study was to determine if a surgical tubing strengthening program can be effective in maintaining the baseball throwing velocity in the treatment group compared to the control group of high school pitchers.

Hypothesis #1

Participation in a shoulder and scapular muscle strengthening program will maintain or increase the pitching velocity of the treatment group over the six-week study as measured by a JUGS radar gun.

\[ H_0: \mu_{\text{post}} - \mu_{\text{pre}} < 0 \]

\[ H_1: \mu_{\text{post}} - \mu_{\text{pre}} \geq 0 \]

Where: \( \mu \) is the mean of the maximum pitching velocities of the subjects, \( \text{pre} \) is pretest, and \( \text{post} \) is posttest.

Hypothesis #2

There will be a significant decrease (\( p < 0.05 \)) in the pitching velocity of the control group over the course of the baseball season as measured by a JUGS radar gun.

\[ H_0: \mu_{\text{post}} - \mu_{\text{pre}} \geq 0 \]

\[ H_1: \mu_{\text{post}} - \mu_{\text{pre}} < 0 \]

Where: \( \mu \) is the mean of the maximum pitching velocities of the subjects, \( \text{pre} \) is pretest, and \( \text{post} \) is posttest.
Hypothesis # 3

There will be a significant difference (p< 0.05) in the change in the pitching velocity of the treatment group compared to that of control group as the result of the six-week program.

\[ H_0: (\mu_{\text{post}} - \mu_{\text{pre}})_T - (\mu_{\text{post}} - \mu_{\text{pre}})_C = 0 \]
\[ H_1: (\mu_{\text{post}} - \mu_{\text{pre}})_T - (\mu_{\text{post}} - \mu_{\text{pre}})_C \neq 0 \]

Where: \( \mu \) is the average pitching velocity, \( T \) is the treatment group, and \( C \) is the control group, \( \text{pre} \) is pretest, and \( \text{post} \) is posttest.

Assumptions

1. Subjects in the treatment group completed the surgical tubing resistance exercise program as instructed, and to the best of their ability.

2. Subjects in the control group did not participate in any form of resistance exercise program for the shoulder and scapular muscles, so as not to confound the results of this study.

Limitations

1. Subjects were not randomly assigned to groups, but rather intact groups were used.

   Random assignment to treatment or control groups was performed for all the pitchers at a particular school. Athletes from the same high school were all in the same experimental group, e.g., all the pitchers of High Schools A and C were assigned to the treatment condition and all the pitchers at High Schools B and D were assigned to the control condition.

2. The level of previous experience in baseball can be a confounding factor in this study.
3. The whole body coordination, and the psychological state of the pitcher during the testing session, can affect the results of this study.

4. The duration of the high school baseball season in Oregon (number of games, number of innings pitched) may not have been long enough to produce fatigue-related reductions in throwing velocity and muscle performance characteristics.

**Delimitation**

The results of this study should only be generalized to male high school baseball pitchers.
CHAPTER 2

In-Season Surgical Tubing Strengthening Program Improves Throwing Velocity Among High School Pitchers

by

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Rod A. Harter, PhD, ATC

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To be submitted to:
The American Journal of Sports Medicine
Abstract

Throughout the various levels of baseball competition, pitchers often suffer season-ending or career-ending injuries. Significant improvements have been made in the treatment and rehabilitation of these injuries, with a lesser amount of attention given to injury prevention. The purpose of this study was to determine the effectiveness of an in-season shoulder and scapular muscle-strengthening program in the maintenance of the throwing velocity among high school baseball pitchers. Twenty-four apparently healthy high school baseball pitchers at four schools volunteered to participate in this study; each school was randomly assigned to either the treatment group or the control group. The treatment group pitchers (n = 12) engaged in a progressive resistance exercise (PRE) strengthening program using Thera-Band® surgical tubing for six weeks, while the control group pitchers (n = 12) did no additional strengthening or stretching activities beyond their normal baseball training. Each subject’s pitching velocity was measured using a JUGS® radar gun at the beginning of and following the six-week study period. Pretest and posttest concentric and eccentric muscular strength and power at 60 and 240 deg/sec were measured for the internal and external rotators of the shoulder using a KinCom 500H isokinetic dynamometer. Results of one-way ANOVAs indicated no significant differences between the groups on any of the experimental parameters at the beginning of the study (p > 0.05). Over the course of the baseball season, pitchers in the treatment group increased their throwing velocity an average of 6.2 mph compared to an average increase of 1.5 mph in the control group (p < 0.001). Group x Time interaction effects (p < 0.03) for 7 of 8 isokinetic peak torque measures indicated significant improvements in shoulder strength in the treatment group at the posttest evaluation. No
time-loss shoulder or elbow injuries occurred in the treatment group during the six-week PRE program. Our results suggest that participation in an in-season PRE program of surgical tubing exercises for the shoulder was safe and successful, not only in maintaining, but significantly improving pitching velocity and the strength of the shoulder internal and external rotators among high school baseball pitchers. Our findings support the use of this low cost surgical tubing PRE program as a means to improve the throwing velocity of high school baseball pitchers.
Introduction

Throughout the various levels of baseball competition, pitchers frequently suffer season-ending or career-ending injuries. In fact nearly every pitcher sustains a major injury at some point in his career. According to NCAA intercollegiate baseball injury surveillance system data for 1998 and 1999, the shoulder was the most frequently injured of all the body parts, accounting for 21% and 14% of all the injuries, respectively. Throwing or pitching was responsible for greater than one-third of practice injuries and about one-fifth of game injuries. According to NCAA injury surveillance system data, the injury rate for baseball (all injuries to all players) was 5.8 per 1000 athletic exposures for 1998 and 6.1 per 1000 athletic exposures for 1999. In 1998, 38% of all injuries restricted participation of the athlete for seven days or more. The frequency of shoulder injuries is not particularly surprising, considering the forces and velocities that are developed during the pitching action.

Much of the existing baseball research has focused on the biomechanics of throwing, clinical management of injuries, and rehabilitation techniques, with a lesser amount of attention given to injury prevention. Time and effort spent in developing and implementing injury prevention programs in baseball can be highly beneficial and contribute to the success and longevity of the player's career. Andrews and Fleisig contend that the steps for preventing pitching injuries must be implemented at the youth level because not only there are significant numbers of pitching injuries in youth baseball, but also the measures implemented in youth baseball may help reduce injuries at higher playing levels.
The number of athletes participating in baseball at middle school and high school levels in the United States far exceeds the number participating in major and minor league professional baseball. However, the degree of health care, strength and conditioning personnel and facilities, and financial support available to the athletes at the professional level is much better than those in the middle school or high school. There remains a significant need of low-cost injury prevention and intervention strategies in this younger age group.

Progressive resistance exercises and strength training have been accepted for all aspects of baseball training and conditioning. Shenk examined the effects of weight training and surgical tubing exercises in NCAA Division I pitchers and observed significant pretest to posttest improvement of maximum pitching velocity of the treatment group compared to the control group. To the best of our knowledge, no previous study has evaluated the effectiveness of an in-season progressive resistance exercise (PRE) program using surgical tubing to strengthen the rotator cuff and scapular muscles in high school baseball pitchers in effort to prevent the injuries to these muscles and to maintain their throwing velocity and performance throughout the season.

The purpose of this study was to determine the effectiveness of a specific scapular and shoulder muscle strengthening program using surgical tubing in the maintenance of pitching performance, i.e., pitching velocity, and improving shoulder muscular strength among high school baseball pitchers.
Methods and Materials

Subjects

Thirty male high school baseball pitchers between the ages of 15 to 19 years were recruited from high schools in Corvallis and Albany, Oregon, to participate in this study. The baseball coaches from four high schools were contacted and informed of the purpose of this study. The coaches' cooperation and permission to have their teams participate in this study during the Oregon School Activities Association-sponsored high school baseball season was obtained. The pitchers and their legally authorized representatives were then contacted with a letter that described the study, together with the informed consent document. All participants or their legally authorized representative gave informed consent prior to the start of the study.

The criteria for inclusion of pitchers in the study included: (a) no history of shoulder injury in the last 6 months, and (b) no history of shoulder surgery. The criteria for exclusion of subjects included: (a) a symptomatic shoulder defined by pain during pretest isokinetic strength assessment, and (b) a pitcher on a participating high school team who did not want to be involved in this study. The subject and, if under 18 years of age, his legally authorized representative read and signed the informed consent document. The Oregon State University Institutional Review Board (IRB) for the Protection of Human Subjects reviewed and approved the methods of this study. Subject demographic data are summarized in Table 2.1.
Table 2.1: Subject demographic data.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± Standard Deviation</th>
<th>Range</th>
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<tr>
<td>Age (years)</td>
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<tr>
<td>Control Group (n = 12)</td>
<td>17.0 ± 1.4</td>
<td>15 - 19</td>
</tr>
<tr>
<td>Treatment Group (n = 12)</td>
<td>16.6 ± 1.0</td>
<td>15 - 19</td>
</tr>
<tr>
<td>Weight (kg)</td>
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<tr>
<td>Control Group (n = 12)</td>
<td>74.1 ± 8.6</td>
<td>57.0 - 90.9</td>
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<tr>
<td>Treatment Group (n = 12)</td>
<td>70.3 ± 11.1</td>
<td>52.3 - 95.5</td>
</tr>
<tr>
<td>Number of pitches during Spring 2000 season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group (n = 12)</td>
<td>542.5 ± 430.9</td>
<td>70 - 1324</td>
</tr>
<tr>
<td>Treatment Group (n = 12)</td>
<td>567.1 ± 320.0</td>
<td>60 - 960</td>
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*No significant differences in the pretest values existed between the treatment and control groups (p >0.05).

Materials

A KinCom 500-H isokinetic dynamometer (Chattecx Corp., Chattanooga, Tennessee) was used to measure peak concentric and eccentric shoulder internal and external rotation torques at 60°/sec and 240°/sec. A custom-built wooden platform with two metal rods and clamps was used to lock down the free standing KinCom accessory chair. Additionally two 20.5 kg dumbbells were attached to the base of the accessory chair to prevent it from rotating during the data collection. A Monark upper body ergometer (Monark, Varberg, Sweden) was used as a warm-up activity prior to concentric and eccentric muscle testing. A JUGS® radar gun (JUGS Company, Tualatin, Oregon) was used to measure the throwing velocity of the pitchers. The treatment group used Thera-Band® surgical tubing (Hygenic Corporation, Akron, Ohio) in 1.4 m lengths of various color-coded tensile strengths (red, green, blue, and black) for the PRE program.
Pilot Study

Prior to the beginning of the study, pilot data were collected to determine the test-retest reliability of JUGS radar gun in measuring maximum pitching velocity. We measured the throwing velocity of five NCAA Division I-A collegiate pitchers at baseball practice one day and then again two days later. Our test-retest reliability was excellent, with an observed intraclass correlation coefficient (ICC) of 0.97. The accuracy of the JUGS radar gun used in this study has previously been reported to be ± 1 mph. 7

Pitching Velocity Evaluation

The pretest pitching velocity assessment for an individual subject was completed during a single session lasting approximately 30 minutes. The pretest evaluations for all subjects were completed within the two-week period prior to the beginning of the Spring 2000 baseball season. The pitching velocity of each subject was measured indoors at their respective high school. Their coaches took the pitchers through a warm-up consisting of active glenohumeral flexion, extension, adduction, abduction, internal and external rotation stretches, and circumduction through the full range of motion. The warm-up also included throwing as many pitches to a catcher as required to feel comfortable before throwing 10 pitches at full velocity, i.e., 10 “fast-balls”.

The velocity of pitching was measured using the radar gun. The pitcher stood on an indoor pitcher’s mound, and was asked to throw 10 pitches using a full wind-up delivery at their fastest speed to the catcher. All testing was conducted indoors to standardize the climatic conditions across days. To compensate for the potential effect of the speed/accuracy trade off, the pitchers were required to throw within a 1.5-m radius of the catcher. Pitches outside this limit were judged unsatisfactory. Subjects repeated this
process until they threw 10 satisfactory pitches. There was no batter and no encouragement or any other type of motivation was given to the pitcher. In accordance with the manufacturer’s recommendations the radar gun was held by the primary investigator (NDB), in line with the path of the baseball, at a distance of 5 m behind the catcher. A protective net screen was placed between the catcher and the primary investigator for latter’s safety (Figure 2.1). Ten satisfactory pitches were recorded, with the fastest five pitches utilized to calculate the average maximum throwing velocity of each subject. The radar gun was recalibrated for each subject. Posttest pitching velocity measurements were obtained at the conclusion of the six-week study period using the identical methodology.

Figure 2.1: Location of the radar gun during pitching velocity data collection.
Isokinetic Shoulder Evaluation

The subject’s peak concentric and eccentric shoulder internal and external rotation torques of the throwing arm were assessed using a KinCom 500-H isokinetic dynamometer. We imposed a mandatory minimum of two days rest between the pitching velocity testing session and muscle strength evaluation to allow the muscles to recover from fatigue. Isokinetic measurements were made according to the protocol previously described by Sirota et al. 13

The dynamometer was calibrated prior to the first pretest isokinetic data collection session. All data collection was done with the subject seated on a free standing accessory chair supplied with the dynamometer. The chair was placed on a wooden frame with a X-Y dimensioned grid used to duplicate the position of the chair at the posttest. The chair was clamped to the wooden frame with metal rods and weighted with two 20.5 kg dumbbells to prevent the rotation of the chair during the testing. The subjects were tested in sitting position with their shoulder in neutral rotation and 90° of abduction and elbow in 90° of flexion. Velcro restraining straps were placed across their shoulders and hips.

Prior to isokinetic testing, each subject warmed up by exercising with an upper body ergometer for 3 minutes at a workload of 300 kgm/min at 100 rpm. At the conclusion of the warm-up activity, the subject was seated on the chair and positioned such that the axis of rotation of the glenohumeral joint was aligned with the axis of rotation of the dynamometer shaft. Dynamometer lever arm length was recorded and the gravity correction protocol was used for each subject.
To minimize learning effects, subjects were familiarized with the dynamometer by asking them to perform five submaximal repetitions at 60°/sec as a warm up. Subjects also performed two maximal repetitions at 60°/sec as a warm up (Figure 2.2).

Figure 2.2: The position and material used for testing shoulder internal and external rotators.

Data were obtained first at 60°/sec and then at 240°/sec, starting with concentric activity and followed by eccentric activity. The order of testing was: concentric internal rotation, eccentric internal rotation, concentric external rotation and eccentric external rotation. The subjects performed six maximum repetitions of each exercise at 60°/sec, with 30 second rest periods between the concentric and eccentric tests. All steps were then repeated with the dynamometer set at 240°/sec.
At the end of the six week treatment period, the subjects had their pitching velocity and isokinetic shoulder strength reassessed. The same investigator (NDB) collected all pretest and posttest strength and pitching velocity data.

**Resistance Exercise Program**

The treatment group followed an in-season shoulder and scapular muscle strengthening program using surgical tubing five days per week for a six week period, beginning the week after the pretest data were collected. The resistance exercise protocol involved concentric and eccentric muscular activity with progressively increasing resistance. During the intervention period, resistance was increased three ways: (a) by changing the distance between the two ends of the tubing, (b) by increasing the number of sets and repetitions, or (c) by changing the resistance (color) of the tubing. Of the four Thera-band® products used in this study, red surgical tubing offered the least resistance, followed in order by green, blue, and black.

The six surgical tubing exercises performed were: standing rowing, forward punches, shoulder shrugging, standing supraspinatus, standing external rotation, and standing internal rotation. Each of these exercises involved both concentric and eccentric muscular activity, with one repetition defined as performance of one concentric and one eccentric phase of a particular resistance exercise.

In the initial two weeks of the intervention, two sets of 10 repetitions of each exercise were performed using red tubing the first week and green tubing during the second week. In the third and fourth weeks, the exercises were performed in three sets of 10 repetitions each using the blue surgical tubing. During the fifth and sixth weeks, the
subjects performed three sets of 12 repetitions of each exercise with black tubing as resistance.

To make the exercises easy for the subjects to perform without having to remember the number of repetitions and sets and the color of tubing, this information was posted on the walls of the weight rooms of the participating high schools. The coach had the responsibility of putting-up the sheets for each week, which was confirmed by NDB. The control group did not incorporate this or any other treatment protocol as a part of their training.

Data Analysis

All statistical analyses were conducted using SPSS version 10.0 software for Windows (SPSS, Inc., Chicago, IL). Data analyses were performed using nine 2 x 2 univariate (treatment/control x pretest/posttest) analyses of variance (ANOVAs) to determine the existence of differences in maximum pitching velocity and eight peak torque variables between the two groups over time (alpha = .05). Significant Group x Time interactions were analyzed further with paired t-tests to determine the location of significance. Since this study was non-randomized, initially one-way ANOVA were performed on the pretest dependent variables to determine if there were any significant differences between the two groups. Differences were accepted as significant at the alpha level of 0.05.

Results

Of the 30 subjects who volunteered to participate, two subjects from the control group and one subject from treatment group quit their respective baseball teams during
the six week period and did not complete the study. One subject in the treatment group had a non-baseball related back injury and did not complete the study. One subject in the treatment could not participate in baseball due to academic ineligibility and was not tested the second time. One subject in the control group declined to participate in the posttest muscle strength testing as the pretest isokinetic testing gave him sore muscles for one week. Therefore, 24 subjects overall, 12 in the treatment group and 12 in the control group, completed the study and were tested at the end of six weeks. There were no pitching related time-loss injuries in either group during the six week study.

Pretest Data Analysis

Results of the one-way ANOVAs for between group differences on the nine dependent variables revealed no significant differences between the control and treatment groups at the outset of the study ($p > .05$).

Maximum Pitching Velocity

Maximum pitching velocity in the treatment group improved an average of 6.2 mph over the course of the study, significantly more than the 1.5 mph improvement observed in the control group ($p < 0.001$) (Table 2.2). A significant Group x Time interaction was also present ($p < 0.001$); however, the post-hoc t-test for simple interaction effects indicated that posttest pitching velocities approached, but did not reach statistical significance ($p = 0.052$). The treatment group had an average posttest pitching velocity of 79.0 mph compared to 75.4 mph in the control group.
Table 2.2: Maximum Pitching Velocity Results.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment (mean ± SD)</th>
<th>Control (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Maximum Pitching Velocity (mph)</td>
<td>72.8 ± 4.6</td>
<td>79.0 ± 3.6</td>
</tr>
</tbody>
</table>

^a p < 0.001.

Concentric Peak Torque Values

There were no significant main effects for Group or Time for any of the concentric measures of peak torque at 60°/sec and 240°/sec (p > 0.32). Three of the four concentric dependent measures had significant Group x Time interactions (p < 0.027). Post-hoc interaction analyses with paired t-tests indicated that only concentric external rotation peak torque at 60°/sec was significantly greater in the treatment group at the posttest (100.1 ± 25.8 Nm) compared to the control group (81.6 ± 16.6 Nm) (p = 0.036).

Figure 2.3: Group x Time Interaction for concentric external rotation peak torque at 60°/sec.
Eccentric Peak Torque Values

There were no significant Group main effects for any of the eccentric measures of peak torque at 60°/sec or 240°/sec. There was a significant main effect for Time observed for eccentric external rotation peak torque at 60°/sec (p = 0.014). Significant Group x Time interactions were present for all four eccentric peak torque measures (p < 0.011). Post-hoc interaction analysis with a paired t-test revealed that the control group’s pretest 60°/sec internal rotation peak torque values significantly decreased from the beginning of the study (113.9 Nm) to the end of the study (98.8 Nm) (p < 0.025). No other simple interaction effects were observed (p > 0.05).

Table 2.3: Concentric and eccentric internal and external rotation peak torque values (mean ± standard deviation) at 60°/sec and 240°/sec.

<table>
<thead>
<tr>
<th>Experimental Parameter</th>
<th>60°/sec</th>
<th>240°/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>Internal Rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Concentric</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td>102.2 ± 29.7</td>
<td>96.3 ± 30.4</td>
</tr>
<tr>
<td>Treatment Group</td>
<td>90.3 ± 25.5</td>
<td>91.3 ± 24.7</td>
</tr>
<tr>
<td><strong>Eccentric</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td>113.9 ± 30.9</td>
<td>98.8 ± 31.2</td>
</tr>
<tr>
<td>Treatment Group</td>
<td>95.7 ± 32.0</td>
<td>97.3 ± 27.8</td>
</tr>
<tr>
<td>Internal Rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Concentric</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td>91.8 ± 21.5</td>
<td>81.6 ± 16.6</td>
</tr>
<tr>
<td>Treatment Group</td>
<td>87.2 ± 21.7</td>
<td>100.1 ± 25.8</td>
</tr>
<tr>
<td><strong>Eccentric</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td>111.1 ± 27.6</td>
<td>98.3 ± 24.1</td>
</tr>
<tr>
<td>Treatment Group</td>
<td>109.9 ± 33.5</td>
<td>118.6 ± 38.8</td>
</tr>
</tbody>
</table>
Table 2.4: Significance values for concentric and eccentric isokinetic variables.

<table>
<thead>
<tr>
<th>Parameter Group</th>
<th>Parameter</th>
<th>Group</th>
<th>Time</th>
<th>Group x Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>60°/sec</td>
<td><strong>Internal Rotation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concentric</td>
<td>0.451</td>
<td>0.331</td>
<td>0.186</td>
</tr>
<tr>
<td></td>
<td>Eccentric</td>
<td>0.425</td>
<td>0.014&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.003&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td><strong>External Rotation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concentric</td>
<td>0.412</td>
<td>0.669</td>
<td>0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
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<td>Eccentric</td>
<td>0.456</td>
<td>0.504</td>
<td>0.002&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>240°/sec</td>
<td><strong>Internal Rotation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concentric</td>
<td>0.647</td>
<td>0.457</td>
<td>0.011&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Eccentric</td>
<td>0.853</td>
<td>0.114</td>
<td>0.011&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td><strong>External Rotation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concentric</td>
<td>0.323</td>
<td>0.585</td>
<td>0.027&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Eccentric</td>
<td>0.334</td>
<td>0.796</td>
<td>0.006&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Statistically significant (p < 0.05)
Discussion

Our statistical analyses indicated there were no significant differences at the beginning of the study on any of the experimental measures between the treatment and control groups (p > 0.05). Through participation in the six-week surgical tubing program, pitchers in the treatment group increased their throwing velocity an average of 6.2 mph compared to an average increase in velocity of 1.5 mph in the control group (p < 0.001). These findings are similar to those observed by Shenk in collegiate baseball pitchers (n = 34) who participated in a strengthening program that used surgical tubing as resistance. However, the resistance exercise regimen used by Shenk included additional surgical tubing exercises such as mimic pitching and reverse pitching that were not included in our study.

In a study with 27 high school baseball pitchers, Wooden et al. reported an average increase of 2.1 ± 1.1 mph in pitching velocity with an individualized, dynamic, variable resistance using isokinetic training for six weeks, while the treatment group in our study demonstrated an average increase of 6.2 ± 2.1 mph.

The findings of our study indicated that control group concentric and eccentric internal and external rotation peak torque values all decreased over the six-week interval between pretest and posttest. In contrast, the treatment group’s isokinetic parameters (8 of 8) all increased following participation in the six-week surgical tubing program. Since the groups were not different at the outset of the study, and the only variable manipulated by this study was participation (or not) in the PRE program, we concluded that the observed improvements were due to the tubing exercises. These treatment effects were not statistically significant, but very encouraging nonetheless. With a larger sample size in
each group and a longer training program (8 to 12 weeks), these trends may have reached statistical significance.

Mont et al.,⁹ in their study with 30 tournament-level tennis players demonstrated average shoulder muscle concentric and eccentric strength gains of 11% in the experimental groups while the control group demonstrated a decrease of 2% in the concentric and eccentric strength. In the current study, the concentric and eccentric muscle activity peak torques increased by about 6% in the treatment group. Our results differed from those by Ellenbecker et al.⁴ who found greater overall strength increase in concentric muscle activity compared to eccentric muscle activity, in a study with 22 collegiate tennis players. The difference could be due to the isokinetic training overflow effect, as Ellenbecker et al.⁴ utilized an isokinetic training protocol.

In an isotonic resistance training program with 22 tennis players, Treiber et al.,¹⁶ found no statistically significant changes in the concentric internal and external rotation peak torque in the control and treatment group over the intervention. The results of our study were similar to those by Treiber et al. Moreover, they found a group by time interaction effect, which is similar to our finding.¹⁶

In our treatment group, the concentric and eccentric internal rotators peak torque increased by about 3%, while the concentric and eccentric external rotation peak torque increased by an average of 10.5%. Treiber et al. observed a 23.8% increase of the internal rotation torque as well as a 17.0% increase of the peak external rotation torque.¹⁶ The smaller concentric peak torque strength gains in our treatment group compared to the Treiber et al. study can be attributed to the fact that their subjects augmented the surgical
tubing program with lightweight dumbbell training. Thus, their regimen offered higher
resistance to the muscles compared to our training program.

Three of the six exercises included in our PRE program concentrated on the
scapular muscles, specifically, the rhomboids, trapezius, and serratus anterior; the
remaining three exercises emphasized the rotator cuff muscles. While increasing the
strength of the glenohumeral internal and external rotators was one of our primary goals,
the important role played by the scapular stabilizers in pitching cannot be overlooked.
However, we did not perform an isokinetic evaluation of the scapular muscles, and thus
cannot comment on their isokinetic strength gains.

We planned to evaluate the effectiveness of the surgical tubing exercises in the
prevention of injuries to the shoulder and elbow during the season. Unfortunately for us,
but very good for the 24 pitchers in our study, there were no time-loss injuries in either
group. Thus, we are unable to comment on the efficacy of our surgical tubing exercise
program in the prevention of shoulder and elbow injuries in baseball pitchers other than
to observe that the in-season program did not cause any overuse injuries. Some strength
and conditioning coaches and pitching coaches may prohibit their pitchers from
participating in an in-season tubing program for fear of inducing an overuse injury to the
rotator cuff musculature. The treatment group pitchers averaged 567.1 pitches during the
season, compared with an average of 542.5 pitches thrown by those in the control group
(p > 0.05). We suggest that this study be replicated with a larger sample size to confirm
our findings that the in-season surgical tubing exercises did not harm, but actually helped
the pitchers.
To our knowledge, no previous study has investigated the possibility of improving pitching velocity and shoulder internal and external rotator strength of the high school pitchers using a surgical tubing training program. We demonstrated that the pitching velocity, and concentric and eccentric peak torque values of the shoulder rotators can be improved using a surgical tubing exercise protocol when compared to not doing this protocol. Our findings suggest that our surgical tubing resistance exercise protocol is an affordable, feasible and effective means of improving performance among baseball pitchers. This strengthening program can be incorporated into the training routines of baseball teams and specifically pitchers as a part of group or individual exercises. The results of this study can have useful implications in all the high schools across the United States.

Whether similar findings will be obtained with this PRE program with intercollegiate and professional level pitchers is yet to be determined. Future investigations should include a treatment period of 8 to 12 weeks to learn if the PRE regimen will result in statistically significant strength gains. We recommend using a larger sample size so as to increase statistical power and decrease the risk of making a Type II error. Finally, we recommend that future studies evaluate throwing velocity during actual baseball games; to compare the effect of surgical tubing exercises on a pitcher’s endurance – the velocity (and control) he can maintain in the later innings of a baseball game.
Conclusion

Our results indicated that participation in an in-season PRE program of surgical tubing exercises for the shoulder was successful in significantly improving pitching velocity, while also increasing concentric and eccentric shoulder internal and external rotator peak torque among high school baseball pitchers.
References


CHAPTER 3

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to determine the effectiveness of a specific scapular and shoulder muscle strengthening program using surgical tubing in the maintenance of pitching performance, i.e., pitching velocity, and improving shoulder muscular strength among high school baseball pitchers.

Summary

The pitching velocity of the treatment group (n = 12) significantly increased over the course of the season (6.2 mph) when compared with the control group (1.5 mph) (p < 0.001). There were no significant main effects for Group or Time for any of the eight concentric and eccentric peak torque measurements at 60°/sec and 240°/sec. However, significant Group x Time interactions (p > 0.03) were present for 7 of 8 isokinetic internal and external rotation peak torques, indicating improved shoulder strength in the treatment group at the posttest evaluation.

Conclusions

Our results indicated that participation in an in-season PRE program of surgical tubing exercises for the shoulder was successful in significantly improving pitching velocity, while also increasing concentric and eccentric shoulder internal and external rotator peak torque among high school baseball pitchers.
Recommendations for Future Research

In event of replicating this study, we would increase the sample size of subjects and thus increase the statistical power of the study. Even though the exercises were equally concentrated on the scapular muscles, these muscles were not included in the isokinetic muscle strength assessments. We recommend performing scapular muscle strength testing in the future.

The scheduling of laboratory data collection sessions for 24 pitchers from four different high schools was the most challenging aspect of this study. The rainy weather, postponed games, and spring break holidays made it difficult to arrange times to test the subjects. Getting a stronger involvement from the parents at the outset and paying the subjects to participate would likely have made the study flow more smoothly.

We recommend the following research questions be addressed in subsequent research investigations:

1. Would similar findings be obtained with collegiate and professional level baseball pitchers as subjects?
2. Would an 8 to 12 weeks duration training program be even more effective at increasing the pitching velocity and peak torques of the shoulder internal and external rotators?
3. Do surgical tubing exercises help pitchers maintain maximum actual pitching velocity into the later innings of a baseball game?
4. What is the effectiveness of a surgical tubing exercise program in the prevention of even after the exercise protocol has concluded.
BIBLIOGRAPHY


Appendix A

OREGON STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD APPLICATION

1. Significance of this project:

According to NCAA injury surveillance system data, the injury rate for baseball was 5.8 per 1000 athletic exposures for 1998, and 6.1 per 1000 athletic exposures for 1999. In 1998, 38% of all injuries restricted participation of the athlete for seven days or more. Unfortunately, most baseball research has been on treatment and rehabilitation, with less attention given to injury prevention. Thus, this research project will evaluate the effectiveness of a specific scapular and shoulder muscle-strengthening program using elastic surgical tubing in the prevention of shoulder injuries, and in the maintenance of the performance of pitching in high school baseball pitchers.

2. Methods and procedures:

There will be two groups of 15 subjects per group. The age of the subjects will range from 13 to 19 years. Subjects will be male baseball pitchers from high schools who have participated in organized baseball and will continue to do so during this intervention study. The subjects should have no history of shoulder injury in last 6 months and no history of shoulder surgery. The duration of this study will be approximately 8 weeks.

At the first experimental session informed consent will be obtained and the subject’s personal data, along with shoulder joint range of motion, muscle strength, and pitching speed will be recorded. The subjects will be tested at the OSU Sports Medicine/Disabilities Research Laboratory using a Kin-Com 500-H isokinetic dynamometer (Chattecx Corp., Chattanooga, Tennessee) to measure concentric and eccentric muscle strength and endurance of the internal rotators and external rotators of the shoulder joint of the throwing arm. Muscular strength will be measured at 60°/sec and 120°/sec. The subjects will then be taken through a warm-up, consisting of movements throughout the full range of shoulder joint motion 20 times for 2 minutes. The warm-up will also include stretching exercises of the shoulder muscles.

Following the warm-up period, the subject will stand on an artificial pitcher’s mound in Women’s Building at Oregon State University and be asked to throw their ‘fast ball’ 10 times to a catcher. The velocity of pitching will be measured using a JUGS radar gun (JUGS Company, Tualatin, Oregon). To compensate for speed/accuracy trade off, the pitchers will have to throw within a 1.5 m radius of the catcher and those pitches outside this limit will be classified as wild pitches and not
recorded. There will be no batter and no encouragement or any other type of motivation will be given. The radar gun will be positioned to the right or left of the pitcher depending on whether he is left-handed or right-handed respectively, at a distance of 5 m from the pitcher, perpendicular to the line joining the pitcher and the catcher. The speed of the baseball will be measured just after leaving the subject’s hand. An average of the fastest 5 pitches will be calculated and recorded. To quantify pitch velocity endurance, the subjects will be asked to throw their ‘fast ball’ 40 additionally pitches within the 1.5 m radius limit. Then their velocity for 10 more pitches will again be measured and averaged for fastest 5 pitches. This pre-testing will be done at the beginning of the baseball practice season.

The subjects will be assigned to either the treatment or the control group according to their school. Those in the treatment group will follow an in-season muscle-strengthening program using surgical tubing daily for approximately 8 weeks, starting the week after the pre-test data are collected. The strengthening protocol will involve concentric and eccentric muscular activity with progressively increasing resistance. The resistance can be increased by two ways, either by changing the distance between the two ends of the elastic surgical tubing or by increasing the number of sets and repetitions. The resistance provided by the tubing will be quantified by placing the force transducer in series with the tubing and recording the value. In all, six exercises will be performed.

These exercises include: seated rowing, forward punches, shoulder shrugs, standing supraspinatus, standing internal rotation and standing external rotation. These exercises involve both concentric and eccentric muscular activity alternately. A repetition of a resistance exercise is defined as a complete movement involving both concentric and eccentric muscle actions. In the first two weeks of the program, the exercises will be performed in 2 sets of 10 repetitions each. In the third and fourth weeks, the exercises will be performed in 3 sets of 10 repetitions each. During the fifth and sixth weeks, the subjects will perform 3 sets of 12 repetition of each exercise. Finally in the last two weeks the subjects will perform 4 sets of 12 repetitions each. The control group will not be participating in this or any other treatment program as a part of their training.

Specific Resistance Exercises:

*Seated rowing:* For this exercise the midpoint of the surgical tubing will be attached to a wall, the height of which will be determined according to the comfort of the subject. The subject will sit on the ground facing the wall with the lower extremity (with knees bent) resting against a support. The subject will hold both the handles attached to the tubing. In the starting position, the subject will slightly flex their elbows and hold them at the waist level, and in the final position, the elbow will be flexed and the scapulae fully retracted. The handles of the tubing will be held horizontal to the ground, and with the forearms pronated, the subject will perform the seated rowing action by flexing the elbows and retracting the scapulae at the shoulder level.
Forward punches: The midpoint of the surgical tubing will be attached to a wall at a height according to the comfort of the subject. The subject will stand with their back facing the wall with their knees slightly bent, and the foot opposite of the throwing arm in front of the other foot. The subject will hold both the handles. In the initial position, the subject will hold the arms against the trunk (shoulders in neutral position), with the elbows flexed at 90°. This exercise involves shoulder flexion and elbow extension, with the hands at shoulder level and arms slightly flexed bent in the final position.

Shoulder shrugs: This exercise will be performed while standing with the subject standing on the tubing and holding one handle in each hand. The shoulders will be initially internally rotated with the elbows extended and the palms facing inwards. The subject will then perform shoulder shrugs by pulling upward on the tubing, elevating the shoulder girdle, and then coming back to the initial position.

Standing supraspinatus: This exercise will be performed in standing position with the subject holding only one handle of the tubing in the throwing hand and securing the other end of the tubing under the foot on the same side. The arm will initially be close to the body with the shoulder slightly internally rotated and the thumb facing upwards. The subject will then perform 90° of shoulder abduction with horizontal flexion at about 30° and then return to the initial position.

Standing internal rotation: The subject will stand and hold one handle of the tubing in the throwing hand and the other end of the tubing will be secured to a rigid support at the height comfortable to the subject. Initially, the subject holds his arm against the trunk with the elbow flexed at 90° and the shoulder positioned in external rotation as much as possible. The subject will then internally rotate his shoulder against the resistance as much as possible and return to the initial position.

Standing external rotation: The subject will stand and hold one handle of the tubing in the throwing hand and the other end of the tubing will be secured to a rigid support at the height comfortable to the subject. Initially, the subject holds his arm against the trunk with the elbow flexed at 90° and the shoulder positioned in full internal rotation in front of the trunk. The subject will then externally rotate his shoulder against the resistance by 90° and return to initial position.

The treatment group will follow this strengthening program for eight weeks and then will participate in a post-test season evaluating the same parameters measured at the pre-test session. The control group of pitchers will not follow this protocol, but will again be tested on the parameters measured in the first session.

All the injuries incurred by the treatment and the control group during the intervention period will be reported to the athletic trainer at the respective high school. The total number of injuries incurred by the treatment and the control group on the throwing shoulder and elbow will be recorded.
3. Benefits and risks:

We do not see any particularly major risk involved with this study. Some occasional discomfort of the involved muscles (mild soreness) due to the resistance exercises may be experienced. This can be treated by the high school’s certified athletic trainer with the application of ice over these muscles. This study may benefit the subjects by maintaining or improving their performance in baseball pitching throughout the duration of the season and also by reducing the incidence of injury to their shoulder musculature. For the group not following this protocol, it is an opportunity to find out the change in their throwing velocity, muscle strength over the season.

4. Subjects:

There will be two groups of 15 subjects per group. The age of the subjects will range from 13 to 19 years. Subjects will be male baseball pitchers from high schools in and around Corvallis, Oregon, e.g., Corvallis High School, Crescent Valley High School, South Albany High School, West Albany High School, who have participated in organized baseball and will continue to do so during this intervention study. The subjects should have no history of shoulder injury in last 6 months and no history of shoulder surgery.

5. Informed consent document:

Enclosed Appendix B.

6. Method of obtaining informed consent:

The subjects will be first given a verbal explanation of the study. A letter (Appendix C) and a copy of the informed consent document will be sent out to the subject’s legally authorized representative either by US mail or through the subject. This letter will be followed by a phone call to the subject’s legally authorized representative by the graduate-student researcher as an opportunity to ask any questions regarding the study. The written informed consent will be read to the subject and an adequate opportunity will be given to the subject and subject’s legally authorized representative to read it before signing it. The subject will be given an opportunity to ask questions to the graduate-student researcher before signing the informed consent. If required, then the graduate-student researcher will schedule a meeting with the subject, subject’s legally authorized representative and the coach.

7. Confidentiality:

Any information that we learn about the subject that can be individually traced to them will be used responsibly and will be protected against release to unauthorized
persons. The Athletic trainer at the high school will be aware of the injury data, which is a normal routine, but will not have access to any other data. The investigating team will not share the results of this study with the coaches. In addition to the members of any health care staff who usually have access to the subject's file, the records will likely be shown to members of the investigation team and faculty interested in the result of this study. The results of this study may be published in the medical literature, but no publication will contain information that will identify the subject. Subjects will be assigned code numbers, and their files will be accessed by password and stored on computer disc available only to the study investigators and maintained in a locked cabinet.

8. **Testing instruments:**

   Kin-Com isokinetic dynamometer, JUGS radar gun, portable pitcher's mound, and elastic surgical tubing.

9. **Other approvals:**

   No other approvals are required for participation in this study.
APPENDIX B

INFORMED CONSENT DOCUMENT

A. **TITLE**: Effectiveness of a Surgical Tubing Strengthening Program in the Maintenance of Performance and the Prevention of Shoulder Injuries Among High School Pitchers.

B. **INVESTIGATORS**: Neeraj D. Baheti, B.Sc. (P.T)  
Rod A. Harter, Ph.D., ATC, Associate Professor.

C. **PURPOSE**: To determine if this protocol is effective in preventing shoulder injuries and in maintaining the “in-season” performance of the pitchers.

D. **PROCEDURES**: I understand that as a participant in this study the following things will happen:

1. **Pre-study Screening**: My eligibility to this study has been determined because I meet the following conditions:
   a. I am in the age range of 13 to 19 years.
   b. I have experience playing baseball and therefore an accomplished thrower.
   c. I have participated in organized baseball and will continue to do so during this intervention study.
   d. I have no history of shoulder injury in last six months.
   e. I have no history of shoulder surgery.

2. **Participation Requirements**: As a participant of this study, I understand that I will be assigned to one of the following groups:
   a. **Group following the protocol**, which will follow the strengthening protocol involving the shoulder muscles for 8 weeks as described by the investigators. I understand that I will be required to come to Oregon State University twice for testing sessions (60-90 minutes each), once before the start of the protocol and then at the end of the study. My personal data including the range of motion at shoulder, throwing speed, shoulder muscle strength will be recorded.
   b. **Group not following the protocol**, which is required to come to Oregon State University twice for testing sessions (60-90 minutes each), as scheduled by the investigators.
3. **Foreseeable risks or discomforts:** Foreseeable risks to myself are minimal. Some occasional discomfort of the involved muscles (mild soreness) due to the exercises may be experienced. This can be treated with the application of ice over these muscles by the athletic trainer at the high school.

4. **Benefits from the Research:** I understand that this study may benefit me by improving my performance in baseball pitching and also reducing the risk of injury to my shoulder muscles. I will also gain information regarding the change in my throwing speed, and my muscle strength over the baseball season.

5. **Alternative course of treatment:** I understand that since the participation in this study is totally voluntary, the alternative is not to participate in this study.

E. **CONFIDENTIALITY:** I understand that any information that the investigators learn about me that can be individually traced to me will be used responsibly and will be protected against release to unauthorized people. The records will likely be shown to members of the investigation team and faculty interested in the results of this study. The Athletic trainer at the high school will be aware of the injury data, which is a normal routine, but will not have access to any other data. If I sign this form, I have given the investigators permission to release information to these people. The investigating team will not share the results of this study with the coaches. The results of this study may be published in the medical literature, but no publication will contain information that will identify me. My written records will be assigned a code number, and will be accessed by password and stored on computer disc available only to the study investigators and maintained in a locked cabinet.

F. **COMPENSATION FOR INJURY:** I understand that I will receive no payment for participating in this study. In the event I suffer physical injury directly resulting from the research procedures, the University will provide no compensation or medical treatment.

G. **VOLUNTARY PARTICIPATION STATEMENT:** I understand that the decision whether or not to participate in this study is completely voluntary and refusal to participate will not involve any penalty or loss of benefits to which I am otherwise entitled. Even if I decide to participate I may stop and withdraw from the study at any time, any penalty or loss of benefits to which I am otherwise entitled. If I withdraw from this study it will not effect my standing on the team. I also understand that the graduate-student researcher should be contacted (737-2210) and the information regarding the withdrawal may be requested.
H. **IF YOU HAVE QUESTIONS:** I understand that any questions I have about the research study or specific procedures should be directed to Neeraj Baheti, 132 Langton Hall, OSU at (541) 737-2210 or Dr. Rod Harter, 226 Langton Hall, OSU at (541) 737-6801.

If I have questions about my rights as a research subject, I should contact the IRB Coordinator, OSU Research Office, (541) 737-8008.

My signature below indicates that I have read and that I understand the procedures above and gives my informed and voluntary consent to participate in this study. I understand that I will receive a signed copy of this consent form.

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Signature of subject’s legally authorized representative (if under 18 years of age)  

Name of Subject

Date Signed  

Subject’s signature

Subject’s Present Address  

Subject’s Phone Number

Signature of Principal Investigator  

Date Signed
APPENDIX C

LETTER TO PARENTS

Date: 

To: 

Subject: __________ participation in a study by OSU.

Dear Parent / Guardian,

We would like to invite __________ for a study by the Department of Exercise and Sports Science (OSU). This study involves an 8-week “in-season” muscle strengthening protocol using surgical tubing in high school baseball pitchers. We are expecting this strengthening program to be successful in preventing shoulder injuries and in improving the throwing speed and muscle strength of the baseball pitchers.

Enclosed herein is a copy of the approval of this study by the OSU Institutional Board (IRB) for the protection of human subjects and the informed consent to participate in this study. You will require signing the informed consent if you are willing to let your son/daughter to participate in this study.

As a follow-up to this letter, I will be soon calling you to answer your questions and concerns regarding this study and other related matters. During the telephonic talk I will offer to schedule an appointment with you at your convenience. You are also invited to see the testing and the equipment used.

Thank you.

_________

Neeraj D. Baheti
Graduate-Student Researcher,
Department of Exercise and Sports Science,
Oregon State University.
## Injury Data

**Name of the High School**

<table>
<thead>
<tr>
<th>Name of the subject</th>
<th>Did he have Shoulder or Elbow injury/pain?</th>
<th>If Yes, then What treatment was given? Ice, Modalities etc.</th>
<th># of days treated. Any rest advised?</th>
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APPENDIX E

COLOR OF TUBING, SETS AND REPETITIONS OF EXERCISE

This week is RED Tubing 2 Sets of 10 Reps
This week is GREEN Tubing
2 Sets of 10 Reps
This week is BLUE Tubing 3 Sets of 10 Reps
This week is BLACK Tubing
3 Sets of 12 Reps
APPENDIX F

EXPERIMENTAL METHODS

Isokinetic shoulder evaluation and Pitching velocity evaluation

The pretest and posttest testing for an individual subject were completed in one day each (60-90 minutes session). The pretest and posttest testing for all the subjects were completed in two weeks each.

Step 1: All the subjects and their legally authorized representative (if under 18 years of age) read and signed the informed consent document (Appendix B) prior to subject’s participation in the study.

Step 2: The subject’s personal data (age, and weight) was obtained during the first testing session.

Step 3: The pitching velocity of the subjects was measured using a standard pitching mound in an indoor setting at the respective high schools. Their coaches took the pitchers through a warm up consisting of stretching by performing flexion, extension, adduction, abduction, internal and external rotation, and circumduction through the full range of shoulder joint. The warm-up also included throwing the ball back and forth with the catcher, throwing as many pitches the pitcher required before throwing 10 pitches at full velocity, i.e., 10 ‘fast-balls’.

Step 4: The velocity of pitching was measured using the JUGS radar gun. The pitcher stood on the pitcher’s mound, and was asked to throw 10 pitches using the wind-up action at their best speed to the catcher. The testing was done in an indoor setting for standardizing the climatic conditions. To compensate for velocity/accuracy trade off, the
pitchers had to throw within 1.5-m radius of the catcher and the pitches outside this limit were classified as wild pitches and were not counted. There was no batter at the plate and no encouragement or any other type of motivation was given to the pitcher. The radar gun was held by the primary investigator exactly behind the catcher, i.e., in line with the path of the ball, at a distance of 5 m from the catcher. A protective screen was placed between the catcher and the primary investigator for latter’s safety. Manufacturers of the radar gun recommended this protocol for maximum accuracy. The 10 satisfactory pitches were all recorded and the fastest 5 pitches were utilized for calculating the average maximum velocity of each pitcher. The radar gun was recalibrated after every subject. This pretest testing was done within two weeks before the baseball season started (pretest testing).

Step 5: The subjects were then tested on KinCom 500-H isokinetic dynamometer for concentric and eccentric strength of shoulder internal and external rotators of the throwing arm. We imposed a mandatory minimum of two days rest between the pitching velocity testing session and muscle strength evaluation to allow the muscles to recover from fatigue. The measurements were made according to the protocol described by Sirota et al. 37

The dynamometer was calibrated prior to the initial isokinetic testing sessions. The testing was done with the subject seated on the free standing KinCom accessory chair. The chair was placed on a wooden frame with a marked grid. The grid was used to mark the position of the chair for each subject. The chair was clamped to the wooden frame with metal rods, to prevent the rotation of the chair during the testing. Additionally a high-friction paper was attached to the base of the wooden frame. Additionally two 25.5-kg. dumbbells were placed on the base of the chair to prevent any movement of the
chair during the testing. The subjects were tested in sitting position with their shoulder in neutral rotation and 90° of abduction and elbow in 90° of flexion, and restraining straps were placed across their shoulders and hips.

As a warm-up, each subject was asked to perform 100 revolutions per minute at workload of 300 kgm/min for 3 minutes using the upper body ergometer. The subject was then seated on the chair and positioned such that the axis of rotation of the shoulder joint was aligned with the axis of rotation of the dynamometer shaft. The height of the chair and the position of the chair on the wooden frame were recorded. The lever arm length was recorded. Gravity correction was performed for each subject. Data was obtained first at 60°/sec and then at 240°/sec, starting with concentric activity and followed by eccentric activity. The internal rotation was tested first followed by external rotation after a rest period of 30 seconds.

a. To minimize the learning effect, the subjects were given a familiarization session on KinCom, by asking them to perform five submaximal repetitions at 60°/sec as a warm up.

b. The subjects performed two maximal repetitions at 60°/sec as a warm up. For all the tests, the activity sequence was concentric → eccentric → concentric → eccentric, for both internal and external rotator muscle groups.

c. The subjects performed six maximal repetitive test activities at 60°/sec in the sequence described in b.

d. Subjects were taken through steps a, b and c at 240°/sec after a rest period of one minute.
Step 6: At the end of 6 week period the subjects were again tested for their pitching velocity and isokinetic shoulder strength. The investigator (NDB) collected all the pretest and posttest data.

Injury data collection

All the injuries incurred by the treatment and the control group (if any) during the intervention period was reported to the certified athletic trainer employed at each of the respective high schools. The total number of injuries incurred by the treatment and the control group on the throwing shoulders were recorded using an injury data collection sheet (Appendix D).

Strengthening program

The treatment group followed an in-season shoulder and scapular muscle strengthening program using surgical tubing daily for 6 weeks starting from the week after the testing. The protocol involved concentric and eccentric muscular activity with progressively increasing resistance. The resistance was increased in three ways, either by changing the distance between the two ends of the tubing; by increasing the number of sets and repetitions; or by changing the resistance (color) of the tubing. Red surgical tubing offered least resistance followed by green, blue and black in order of increasing resistances. The resistance offered by the surgical tubing was previously quantified by placing a spring balance in series with the tubing and statically loading the surgical tubing at different lengths and recording the reading on the spring balance.

In all six surgical tubing exercises were performed. These exercises included: standing rowing, forward punches, shoulder shrugging, standing supraspinatus, standing
external rotation and standing internal rotation. All these exercises involved both concentric and eccentric muscular activity. Performance of the concentric and eccentric phases of a particular resistance activity was defined as one repetition. In the first two weeks, the exercises were performed at two sets of 10 repetitions each using red tubing the first week and green tubing during the second week. In the third and fourth weeks, the exercises were performed in three sets of 10 repetitions each using the blue surgical tubing. During the fifth and sixth weeks, the subjects performed three sets of 12 repetitions of each exercise with black tubing as resistance.

To make the exercises easy for the subjects to perform without having to remember the number of repetitions and sets and the color of tubing, this information (Appendix E) was posted on the walls of the weight rooms of the participating high schools. The coach had the responsibility of putting-up the sheets for each week. The control group did not incorporate this or any other treatment protocol as a part of their training.

**Specific Resistance Exercises**

1. **Standing Rowing:**

The midpoint of the surgical tubing was secured to a rigid support, the height of which was determined according to the comfort of the subject. The subject held both the handles attached to the tubing. In the starting position, the subject slightly flexed their elbows and held them at the waist level, and in the final position, the elbow was flexed and the scapulae fully retracted. The handles of the tubing were held horizontal to the ground, with the forearms pronated and then the subject performed the standing rowing action by flexing the elbows and retracting the scapulae at the shoulder level.
2. Forward punches: 16

The midpoint of the surgical tubing was secured to a rigid support at a height according to the comfort of the subject. The subject stood with their back facing the wall, their knees slightly bent, and the foot opposite of the throwing arm in front of the other foot. The subject held both the handles of the tubing. In the starting position, the subject held the arms against the trunk (shoulders in neutral position), with the elbows flexed at 90°. This exercise involved shoulder flexion and elbow extension, with the hands at shoulder level and elbows slightly bent in the final position.

3. Shoulder shrugging: 16

This exercise was performed while standing with the subject standing on the tubing and holding one handle in each hand. The shoulders were initially internally rotated with the elbows extended and the palms facing inwards. The subject then performed shoulder shrugs by pulling upward on the tubing, elevating the shoulder girdle, retracting and then coming back to the initial position.

4. Standing supraspinatus: (full can) 36

This exercise was performed while standing with the subject standing on the tubing and holding one handle in each hand. The arms were initially close to the body with the shoulders slightly externally rotated with the thumbs facing upwards (full can) as Itoi et al. 17 found the full can position to be more beneficial for clinical testing. The subject then performed 90° of shoulder abduction with horizontal flexion at about 30° and then returned to the initial position.
5. Standing external rotation: The subject stood and held one handle of the tubing in the throwing hand and the other end of the tubing was secured to a rigid support at the height comfortable to the subject. Initially, the subject held his arm against the trunk with the elbow flexed at 90° and the shoulder positioned in full internal rotation in front of the trunk. The subject then externally rotated his shoulder against the resistance by 90° and returned to the initial position.

6. Standing internal rotation: The subject stood and held one handle of the tubing in the throwing hand and the other end of the tubing was secured to a rigid support at the height comfortable to the subject. Initially, the subject held his arm against the trunk with the elbow flexed at 90° and the shoulder positioned in external rotation as much as possible. The subject then internally rotated his shoulder against the resistance as much as possible and returned to the initial position.
APPENDIX G

REVIEW OF LITERATURE

The review of literature is divided into six sections. The first is the review of functional anatomy of the rotator cuff. The next section addresses the biomechanics of pitching. The third and fourth sections discuss the role of the acromion structure and the shoulder impingement syndrome, respectively. The fifth section discusses the positioning of the shoulder and the forces used to measure the shoulder muscle strength. Finally, the throwing velocity measurement protocols are discussed in the last section.

Rotator Cuff Functional Anatomy

The rotator cuff is comprised of four muscles: supraspinatus, infraspinatus, teres minor, and subscapularis, and are conjoined to regions of the glenohumeral joint capsule. All four muscles have their origin on the scapula and insert on the humeral head. The supraspinatus and infraspinatus muscles originate from supraspinatus fossa, and infraspinatus fossa, respectively; the subscapularis originates from subscapularis fossa and teres minor muscle from the middle two-thirds of the lateral border of the posterior surface of scapula. The supraspinatus, infraspinatus and teres minor have their insertions along the anterior, posterolateral, and posterior aspects of the greater tuberosity respectively and the subscapularis tendon has its insertion at the lesser tuberosity. The deeper tendinous fibers of the individual muscle intertwine and fuse to form the continuous cuff along with the capsule of the glenohumeral joint at the tuberosities.

The long head of the biceps penetrates the rotator cuff between the supraspinatus and subscapularis tendons and passes over the humeral head to insert into the radial
tuberosity of the radius. The subacromial-subdeltoid bursae act as a lubricating medium under the coracoacromial arch for the cuff tendons to move with less friction. The coracoacromial arch forms the roof over the rotator cuff. The structures forming this arch include the acromion, the acromio-clavicular joint, the coracoid process, and the coracoacromial ligament. The space between the humeral head and the coracoacromial arch is known as the subacromial space or the supraspinatus outlet.

**Biomechanics of Pitching**

The action in baseball pitching can be divided into six phases. The windup phase starts when the pitcher makes the first movement and ends when the lead leg is lifted and the throwing hand is removed from the glove. This first phase is followed by stride phase, which ends when the forefoot contacted the ground. The third phase termed the cocking phase, ends when the throwing arm reaches maximum external rotation. Initiation of the forward arm movement begins the acceleration phase, which ends with the ball release. The period of time from ball release until the arm reaches maximum internal rotation is called the deceleration phase, which is followed by the follow-through phase, ending when the pitcher stops his movements.

One of the critical events of pitching occurs shortly after the ball is released during the deceleration phase, when large compressive forces are generated in shoulder to resist distraction of glenohumeral joint due to the pitching action. Since the rotator cuff muscles primarily act as a unit to produce dynamic compression on the shoulder joint to prevent the glenohumeral joint distraction, the eccentrically acting posterior rotator cuff muscles absorb most of the forces produced during arm deceleration phase, causing injury to them. Due to repeated pitching action by the pitcher over the course of a
season, the rotator cuff muscles typically fatigue, and an overuse injury, i.e., an injury due to accumulated microtrauma due to repeated stress, occurs.  

Role of Acromion Architectural Structure

Bigliani et al. ³ identified three different anatomical types of the acromion process: type I (flat), type II (curved/concave), and type III (hooked) based on the appearance of the inferior surface of the acromion process of the scapula.

![Diagram of Acromion Types](image)

Fig 1: Shapes of acromion from a lateral perspective of shoulder. Type I is a flat acromion (a), type II is curved (b), and type III is the hooked type (c). Reprinted with modification from: Wolin PM, and Tarbet JA: Rotator cuff injuries: addressing overhead overuse. Phys Sports Med 25(6): 54-74, 1997.

Neer's hypothesis of a relationship between the acromion structure and the impingement syndrome has been supported by demonstration of a positive relationship between inferior acromion spurring and rotator cuff tears. ³¹ Various researchers have found type II and type III acromion process to be closely related to the impingement syndrome of rotator cuff. ², ³, ⁶ The more the acromion is curved, the greater the chance of a tear of the rotator cuff muscles. ³¹ Acromioplasties of the inferior acromion have been performed on those with rotator cuff tears to achieve a flat surface and these have produced reduced pain and symptoms related to the shoulder. ³¹ MacGillivray et al. found
that with the increasing age, there are a greater percentage of patients with more curved acromion structure. 22

**Shoulder Impingement Syndrome**

Shoulder impingement syndrome can be classified into either a primary or secondary type. 19 Primary impingement is caused mainly due to crowding or stenosis of the subacromial space. Also called “classic” or “true impingement”, primary impingement is caused by a variety of anatomical reasons such as a hooked acromion, bicipital tendonitis, calcific deposits in subacromial bursa, and subacromial bursitis. 19

Secondary impingement, also referred to as functional impingement is usually seen in younger athletes with overhead activities, and usually associated with glenohumeral instability which may be either traumatic or atraumatic (subtle). 44 The former is usually seen in contact sports and caused due to forceful abduction and external rotation of the arm, while the latter is usually due to repetitive microtrauma and seen in athletes involved in throwing or other overhead activities. 5,44 Due to the repeated overhead activity, the anterior band of the inferior glenohumeral ligament complex (IGHLC) is stretched. The IGHLC acts to support the humeral head, and when this structure becomes lax and elongated, the humeral head is no longer well controlled and subluxates. This phenomenon is known as creep deformation and can occur in all human tissues.

Since all the rotator cuff muscles originate on the scapula and insert into the humerus, the scapula must provide a strong base for the rotator cuff muscles to act. The primary scapular muscles (serratus anterior, rhomboids, trapezius) must act synergistically to stabilize the scapula to the thorax. These scapular stabilizers play a very
important role in the scapulo humeral rhythm, and in positioning the glenoid for articulation with the humeral head. With the repeated overhead activity by the athletes such as baseball pitchers, the scapular stabilizers tend to become weak and fatigued. This weakness and fatigue may be compounded by presence of injured rotator cuff muscles that are unable to guide the humeral head around the coraco-acromial ligament during overhead activities.

On the anterior side of the trunk, the chest wall muscles have a greater physiologic cross-sectional area and thus are “stronger” than posterior chest wall muscles, causing the scapula to protract and thus the glenoid fossa to antevert. Glenoid anteversion reduces the bony restraint to anterior humeral translation, leading to a subtle anterior instability. Also, due to weakness of the scapular stabilizers, the scapula tends to be depressed, which in turn reduces the subacromial space and predisposes the rotator cuff muscles to impingement. Thus, the above sequence of events leads to a condition of abnormal kinematics termed as scapular dyskinesis and can eventually lead to subacromial impingement, instability, and dislocation of the shoulder joint.

The normal action of infraspinatus, teres minor, and the subscapularis muscles is to pull the humerus inferiorly into the glenoid fossa. In pitchers with an abnormal kinematics, these muscles become weak, resulting in reduced opposition to the deltoid muscle’s upward pull on the humerus. This imbalance permits abnormal superior translation of the humeral head eventually resulting in impingement of the rotator cuff between the acromion process and the head of the humerus. Thus, the maintenance of normal balance between the strength of scapular and rotator cuff muscles is important for
maintaining the normal rhythm between the scapula and humerus and in turn to prevent shoulder instability and the impingement syndrome.

In athletes with overhead activities like in baseball pitching, there is tensile force acting on the rotator cuff. During the deceleration phase, the posterior rotator cuff muscles are subjected to large eccentric forces, which produce maximum muscle tension, and can lead to their fatigue and tear. Magnasson et al. found that the pitchers have weaker muscles on their throwing arm and that the eccentric muscular gains from the pitching are insufficient to the demand and could lead to weakness and thus predispose the muscles to injury.

According to Matsen the rotator cuff damage follows a cyclic path. If the rotator cuff is damaged (injured) for any reason, this will cause impaired function and an inability to depress the humeral head. The humeral head thus translates superiorly, resulting in primary impingement and compression of the rotator cuff blood supply eventually causing additional cuff damage and additional impaired function.

Positioning of Shoulder and the Torque Measured

Rotation is an important function of the shoulder and the action of pitching. Torque is the resultant of the forces acting on a body due to its rotational movement, and is generated perpendicular to the axis of rotation. Torque is the measure of the rotational force; Wilk et al. and Kuhlman et al. consider rotational force a measure of strength. Thus, the torque values represent important indicators of the shoulder strength.

Depending on the position of the glenohumeral joint, significantly different torque values have been obtained for the glenohumeral muscles. Soderberg and Blaschak demonstrated shoulder in 90° abduction and elbow in 90° flexion to be an optimal test
position for measuring shoulder external rotation strength with the subject seated and trunk, and hips stabilized using straps. \(^{38}\) Falkel et al. found that testings on an athlete, in sports-specific positions and postures yield higher values than those obtained from non-sports-specific positions \(^{12}\) and thus, in the present study, position of shoulder in 90° abduction and elbow in 90° flexion was used quantifying the shoulder internal rotation strength because this position most closely approximates the throwing position. \(^{36}\)

**Throwing Velocity Measurement Protocols**

Wooden et al. \(^{46}\) positioned the radar gun to the right of the catcher at a height of 36 inches and instructed the pitcher to use a wind-up motion to throw the baseball. Shenk \(^{36}\) used a fixed target instead of a catcher and placed the radar gun four feet behind and slightly to the right of the target for the right-handed pitchers and four feet behind and slightly to the left of the target for the left-handed pitchers. For maximum accuracy, the manufacturers of the JUGS radar gun recommended the radar gun to be placed in line with path of the ball. \(^{18}\) Thus in the present study, the primary investigator held the radar gun exactly behind the catcher. A protective screen was placed between the catcher and the primary investigator for latter’s safety. The testing was recommended in an indoor setting for standardizing the climatic conditions. \(^{18,36}\) Shenk \(^{36}\) and Pedegena et al. \(^{33}\) recorded three maximal effort throws, while Wooden et al. \(^{46}\) recorded five maximal effort throws. In this study, 10 pitches were recorded and the fastest 5 pitches were averaged to be maximum throwing velocity of the pitcher. The radar gun was recalibrated after every subject. \(^{18,33,36,46}\)
The accuracy of the radar gun mentioned by the manufacturer has been shown to be ± 1 mph. In a pilot study by Mont et al. a ball-to-ball velocity variation of ± 2 mph was recorded.