THE RELATIONSHIP BETWEEN SHOULDER STRETCHING AND THROWING VELOCITY IN HIGH SCHOOL BASEBALL PLAYERS

A THESIS

Submitted to the Faculty of the School of Graduate Studies and Research of California University of Pennsylvania in partial fulfillment of the requirements for the degree of Master of Science

by

Masanao Fujimoto

Research Adviser, Dr. Bruce D. Barnhart

California, Pennsylvania

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CALIFORNIA UNIVERSITY OF PENNSYLVANIA
CALIFORNIA, PA

THESIS APPROVAL

Graduate Athletic Training Education

We hereby approve the Thesis of

Masanao Fujimoto
Candidate for the degree of Master of Science

Date Faculty

5-5-08

Bruce D. Barnhart
Dr. Bruce D. Barnhart

5-5-08

Jamie Foster
Dr. Jamie Foster

5-5-08

Dr. Edwin M. Zuchelkowski
Dr. Edwin M. Zuchelkowski
ACKNOWLEDGEMENTS

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Shoulder static or passive stretching is widely performed before baseball practices or games, especially with pitchers, and baseball players have been taught this technique as the appropriate way for pre-activity warm-up.\textsuperscript{1} Stretching includes ballistic, static, active, Proprioceptive Neuromuscular Facilitation (PNF), and dynamic stretching. It is believed that the benefits of stretching include increases in flexibility and range of motion (ROM). Stretching is one of the techniques which enhance the ROM at a given articulation by changing the extensibility of the muscle and tendon that create movement at that joint.\textsuperscript{2} Many pitchers stretch their shoulder before they pitch to loosen up the shoulder musculature. However, stretching before explosive activity or competition may decrease force and power.\textsuperscript{3-8}

Stretching is one of the commonly used techniques to warm up the muscle, and to increase ROM and flexibility, which is defined as the ability to move the joint throughout the ROM.\textsuperscript{2,9,10}
The movement of the shoulder joint is critical for range of motion and to produce maximal force when throwing the baseball. The shoulder is allowed three degrees of freedom, flexion/extension, abduction/adduction, external rotation/internal rotation and circumduction, and reinforced for stabilization by musculature and ligamentous tissues. The shoulder complex consists of four joints or articulations; the sternoclavicular joint, the acromioclavicular joint, the glenohumeral joint, and the scapulothoacic articulation.\textsuperscript{11}

Proper coordination of the muscles and biomechanics of the upper extremity is important to produce sufficient force.\textsuperscript{12} Two factors are needed to deliver a fast ball: the acceleration of the upper extremity; and the distance that the extremity travels. Maximum throwing velocity potential is generated by optimal throwing mechanics.\textsuperscript{13}

The throwing phases consist of windup, cocking, acceleration, deceleration and follow-through phases. The wind-up phase starts from the first movement of the throwing motion until the ball leaving the opposite hand of the glove.\textsuperscript{14}
The cocking phase starts when lead leg contacts on the ground to the point at maximal shoulder external rotation (ER). The acceleration phase is defined as the time period between the point of maximal shoulder ER and rapid release and acceleration of the ball. Deceleration phase occurs following ball release. The shoulder muscles resist shoulder distraction, to slow arm rotation, oppose anterior subluxation forces, and aid to decelerate the abducting shoulder in this phase. Follow-Through phase is continuation movement from the deceleration of the throwing arm. The throwing arm should have a long follow through path, permitting the energy to be dissipated over a longer time to reduce the required deceleration force. The correct mechanics of the follow-through include that the pitching hand will finish near the opposite side of the leg.

Stretching is widely used for relaxing and elongating a muscle to increase ROM and prevent injury. However, there are few studies that explain the exact optimal duration time of stretching. Bandy and Irion demonstrated three different
kinds of hamstring stretching duration, 15 seconds, 30 seconds and 60 seconds to examine the length of time to obtain maximal flexibility. They concluded that the most effective duration is 30 seconds and that 15 seconds of stretching is not effective.\textsuperscript{10}

Recent studies showed that stretching before explosive activity or competition may decrease force and power\textsuperscript{3-8} by approximately 2\% to 5\%, along with explosiveness of the movement.\textsuperscript{6} Although acute episodes of stretching decrease power output, long-term stretching enhances performance and improves both power and force when performed consistently for several weeks.\textsuperscript{6,7}
METHODS

The methods provide an overview of the conduct of this study. This section includes the following: research design, subject, preliminary research, instruments, stretching protocol, procedure, hypotheses and data analysis.

Research Design

A quasi-experimental within subject design was used for this study. The independent variables were Proprioceptive Neuromuscular Facilitation (PNF) stretching, static stretching and control. The dependent variables were pre and post active range of motion (AROM) for external rotation (ER) and internal rotation (IR), and pre and post baseball thrown velocity. Each subject was measured in a randomly assigned order under each condition and served as their own control group.

Both pitchers and field players were used as the subjects
for this study. A strength of this study was that each subject acted as their own control, so it is easy to compare the results. A weakness of this study is that the subjects are from a small high school, so only seven pitchers participated in this study.

Subjects

The subjects (N = 18) were baseball players from California Area High School who volunteered. Subjects who had a previous history of injury to the throwing shoulder within one year of the study were excluded. Demographic information sheet included the questions about the injuries: whether the subject had an injury within one year of the study, what kind of shoulder injury and date of injury, and if the subject currently had pain with throwing. The subject who was out of activity for more than seven days from an injury within one year of the study or who currently had pain with throwing was excluded from this study. Players were selected regardless of the position they played.
Preliminary Research

The purpose of the preliminary research was to familiarize the researcher regarding the instruments needed, to conduct the experiment smoothly for each subject, to become accustomed to the speed gun and to become familiar with the stretching procedures. Preliminary research subjects were comprised of California University of Pennsylvania athletic training students.

Instruments

The following instruments were used for this study: a demographic sheet, the STALKER Sport speed gun which is the name of the device to measure throwing velocity, and a 360 degree goniometer to assess the subject’s active range of motion (AROM). The demographic sheet included information such as year in school, years experience in baseball, throwing arm, position, question regarding injury, current stretching program prior to practice before this study, and the subject’s perception of stretching before and after the stretching
protocol.

Stretching Protocol

To conduct the static stretching of the shoulder external and internal rotators (ER and IR respectively), the subject was placed supine on the table to stabilize the scapula with the shoulder abducted at 90 degrees and the elbow flexed at 90 degrees. The researcher stood on the same side of the stretching shoulder. To stretch the ER, the shoulder was internally rotated to the point where subject felt discomfort,\textsuperscript{5,10} and statically held in a stretch for 30 seconds. To stretch the IR, the shoulder was externally rotated to the point where subject felt discomfort,\textsuperscript{5,10} and statically held in a stretch for 30 seconds. This static stretching for both ER and IR were repeated three times. The subjects then had a 10 second interval between the stretching for the relaxation. The order of stretching was not randomized, therefore ER stretching was performed followed by IR.

To conduct the Proprioceptive Neuromuscular
Facilitation (PNF) stretching, a hold-relax technique was used for ER and IR stretching. The subject was placed supine on the table to stabilize the scapula with the shoulder abducted at 90 degrees and the elbow flexed at 90 degrees. The researcher stood on the same side of the stretching shoulder. To perform the ER stretch, the shoulder was internally rotated passively to the point where subject felt discomfort.\textsuperscript{5,10} The position was held for ten seconds, and then the subject performed a maximum isometric contraction of ER for six seconds against maximum resistance given by the researcher. To perform the IR stretch, the shoulder was externally rotated passively to the point where subject felt discomfort.\textsuperscript{5,10} The position was held for ten seconds, and then the subject performed a maximum isometric contraction of IR for six seconds against maximum resistance given by the researcher. This stretching procedure for both ER and IR were repeated three times. The subjects then had ten second interval between the stretching for the relaxation. The order of stretching was not randomized, therefore ER stretching was performed followed by IR.
Procedures

The following steps were taken to conduct this study: approval was obtained from the California Area High School, and approval from California University of Pennsylvania’s Institution Review Board for the Protection of Human Subjects (IRB). Once the study was approved, the researcher informed the baseball players at the beginning of the baseball season in January. Volunteers who were interested received consent forms for both the players and their parents to complete. When athletes scheduled for the experiment, the consent forms were submitted to the researcher and the subjects were randomly assigned to the group they would be in by picking a number out of a bag. Assigned groups were: Group 1 (control, static, PNF), Group 2 (control, PNF, static), Group 3 (static, control, PNF), Group 4 (static, PNF, control), Group 5 (PNF, control, static), and Group 6 (PNF, static, control). Three subjects were assigned to each group. To begin the experiment, the subjects performed their regular warm up with the team. There was no limitation to what they could do, such as jogging, tossing,
sprinting etc, during the warm-up. After the warm up was completed, each subject was called and had their IR and ER AROM measured using the goniometer. The fulcrum of the goniometer was placed on the olecranon process of the elbow, the stationary arm was placed parallel to the middle of the trunk, and the moving arm was placed along the ulna. Then the assigned stretching was provided. When the subject was being tested as part of the control group, no stretching was provided. After stretching was completed, the subjects had IR and ER AROM measured again, and proceeded to the baseball field and tossed the ball to warm up the shoulder for 10 minutes. Pitchers threw the baseball from the mound to the catcher, a distance of sixty feet and six inches. The field players, to avoid the awkwardness of throwing from the mound, threw the baseball the same distance from the field to the catcher. After the warm up the first ten throws of the fastball were measured and recorded. Following this, the AROM of the throwing shoulder was reassessed and recorded.
Hypotheses

The following hypotheses are tested in this study

1. Shoulder IR and ER ROM will be different after both static and PNF stretching.

2. The average throwing velocity will be different for the static and PNF stretching group compared to the control group.

3. The ROM for (1) IR and (2) ER will be different between PNF and static stretching.

Data Analysis

All tests of statistical significance used an alpha level of .05. Data was analyzed using the SPSS statistical software package, version 14.0.

1. A repeated measure ANOVA will be used to determine if shoulder IR and ER ROM will be different after both static and PNF stretching.

2. A one way ANOVA will be used to determine if the average
throwing velocity will be different for the static and PNF stretching group compared to the control group.

3. A MANOVA will be used to determine if the ROM for (1) IR and (2) ER will be different between PNF and static stretching.
RESULTS

Demographics

The subjects for this study were eighteen high school baseball players from a Southwestern Pennsylvania, class A high school. None of the subjects had an injury or current pain to their throwing arm within one year of the study. The players included two seniors, three juniors, six sophomores and seven freshmen. Fourteen were right hand dominant and four were left handed. Positions they played included seven pitchers, two catchers, ten infielders and six outfielders. The pitchers also play either infield or outfield, therefore they were counted twice when tallying positions.

Hypotheses Testing

Three hypotheses were tested and results were calculated. All hypotheses were tested using SPSS version 14.0. Tests of statistical significance used an alpha level of .05.

Hypothesis 1: Shoulder internal rotation (IR) and external rotation (ER) range of motion (ROM) will be different after both static and PNF stretching.

Means were calculated for ROM under each stretching protocol. A repeated measures ANOVA was calculated comparing
the ROM of subjects using three different stretching techniques: control, static stretching, and PNF stretching. Table 1 shows the effect on IR ROM by each stretching protocol. Table 2 shows the effect on ER ROM by each stretching protocol. Table 3 and 4 shows the relationship among the stretching protocols.

**Table 1:** Effect of IR ROM under each stretching protocol

```
Tests of Within-Subjects Effects

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**Table 2:** Effect of ER ROM under each stretching protocol

```
Tests of Within-Subjects Effects

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**Table 3:** Relationship among stretching

```
Paired Samples Statistics

<table>
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<tr>
<th>Pair</th>
<th>Difference in IR ROM in static stretching</th>
<th>Difference in IR ROM in PNF stretching</th>
<th>Difference in IR ROM in control</th>
<th>Difference in ER ROM in static stretching</th>
<th>Difference in ER ROM in PNF stretching</th>
<th>Difference in ER ROM in control</th>
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<td>Std. Error Mean</td>
<td>Mean</td>
<td>Std. Deviation</td>
<td>Std. Error Mean</td>
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<td></td>
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<td>.00000</td>
<td>.00000</td>
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<tr>
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</tr>
<tr>
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<td>5.24685</td>
<td>1.23669</td>
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```

DstaticIR=Difference in IR ROM in static stretching, DPNFIR=Difference in IR ROM in PNF stretching, DcontrolIR=Difference in IR ROM in control, DstaticER=Difference in ER ROM in static stretching, DPNFER=Difference in ER ROM in PNF stretching, and DcontrolER=Difference in ER ROM in control.
Table 4: Paired Sample Test

<table>
<thead>
<tr>
<th>Pair 1</th>
<th>DstaticIR - DPNFIR</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>Sig.</th>
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</thead>
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<tr>
<td>Pair 3</td>
<td>DcontrolIR - DPNFIR</td>
<td>-6.000</td>
<td>6.79100</td>
<td>1.60065</td>
<td>.002</td>
</tr>
<tr>
<td>Pair 4</td>
<td>DcontrolER - DstaticER</td>
<td>-4.055</td>
<td>3.45513</td>
<td>.81438</td>
<td>.000</td>
</tr>
<tr>
<td>Pair 5</td>
<td>DstaticER - DPNFER</td>
<td>0.05556</td>
<td>5.67214</td>
<td>1.33694</td>
<td>.967</td>
</tr>
<tr>
<td>Pair 6</td>
<td>DcontrolER - DPNFER</td>
<td>-4.00000</td>
<td>5.24685</td>
<td>1.23669</td>
<td>.005</td>
</tr>
</tbody>
</table>

DstaticIR=Difference in IR ROM in static stretching, DPNFIR=Difference in IR ROM in PNF stretching, DcontrolIR=Difference in IR ROM in control, DstaticER=Difference in ER ROM in static stretching, DPNFER=Difference in ER ROM in PNF stretching, and DcontrolER=Difference in ER ROM in control.

Conclusion: A significant effect was found (F (2, 34) = 8.258, p = 0.001) for internal rotation, and (F (2, 34) = 8.153, p = 0.001) for external rotation. Follow-up paired samples test revealed that IR ROM increased significantly from control to static stretching M = 3.61 ± 3.74, and from control to PNF stretching M = 6.00 ± 6.79. There was no significant difference from static M = 3.61 ± 3.74 to PNF stretching M = 6.00 ± 6.79. ER ROM increased significantly from control to static stretching M = 4.06 ± 3.46, and from control to PNF stretching M = 4.00 ± 5.25. There was no significant difference from static stretching M = 4.06 ± 3.46 to PNF stretching M = 4.00 ± 5.25.

Hypothesis 2: The average throwing velocity will be different for the static and PNF stretching groups compared to the control group.

Means were calculated for throwing velocity by each stretching protocol. A one way ANOVA was calculated to compare average velocity in control group to average velocity in
stretching groups. Table 5 and 6 shows the comparison of mean velocity by each stretching protocol.

**Table 5:** Comparison of mean velocity by each stretching protocol

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
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<td>80.70</td>
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<td>2.00</td>
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<td>65.8722</td>
<td>5.72803</td>
<td>1.35011</td>
<td>54.10</td>
<td>81.10</td>
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<td>3.00</td>
<td>18</td>
<td>66.9000</td>
<td>5.51639</td>
<td>1.30023</td>
<td>56.40</td>
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<tr>
<td>Total</td>
<td>54</td>
<td>66.5741</td>
<td>5.45490</td>
<td>.74232</td>
<td>54.10</td>
<td>81.10</td>
</tr>
</tbody>
</table>

Group1=control, Group2=Static, and Group3 =PNF

**Table 6:** ANOVA

<table>
<thead>
<tr>
<th>Sum of Squares</th>
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<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
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<tbody>
<tr>
<td>Between Groups</td>
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<td>13.323</td>
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</tr>
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<td>Within Groups</td>
<td></td>
<td>1563.741</td>
<td>30.662</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1577.064</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion: The mean velocity from each condition, control, static stretching and PNF stretching were compared using a one-way ANOVA. No significant difference was found (F (2,51) = .217, p = .805). The mean velocity from the control and two different stretching did not differ significantly.

Hypothesis 3: The ROM for (1) IR and (2) ER will be different between PNF and static stretching.

A MANOVA was calculated examining the effect of ROM on PNF and static stretching. Table 7, 8 and 9 shows the effect of IR and ER ROM on PNF and static stretching.
Table 7: Effect of IR and ER ROM on PNF and static stretching
Multivariate Tests(c)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>.006</td>
<td>2500.172(a)</td>
<td>3.000</td>
<td>49.000</td>
<td>.000</td>
</tr>
<tr>
<td>Group</td>
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<td>4.651(a)</td>
<td>6.000</td>
<td>98.000</td>
<td>.000</td>
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</tbody>
</table>

Table 8: Tests of Between-Subjects Effects

<table>
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<th>Source</th>
<th>Dependent Variable</th>
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<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
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<td>8.194</td>
<td>.001</td>
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<td>DER</td>
<td>2</td>
<td>97.352</td>
<td>7.400</td>
<td>.002</td>
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<tr>
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<td>Velocity</td>
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<td>6.661</td>
<td>.217</td>
<td>.805</td>
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<tr>
<td>Intercept</td>
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<td>27.650</td>
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<td>7805.655</td>
<td>.000</td>
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<tr>
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<td>8.194</td>
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<td>97.352</td>
<td>7.400</td>
<td>.002</td>
</tr>
<tr>
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<td>Velocity</td>
<td>2</td>
<td>6.661</td>
<td>.217</td>
<td>.805</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Velocity</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
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<tr>
<td></td>
<td>Velocity</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DIR=Difference in IR ROM, DER=Difference in ER ROM, Group1=control, Group2=Static, and Group3=PNF

Table 9: Multiple Comparisons

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Std. Error</th>
<th>Sig.</th>
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</thead>
<tbody>
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<td>.001</td>
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<td>.005</td>
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<td>1.20903</td>
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<tr>
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<td></td>
<td>3.00</td>
<td>1.00</td>
<td>1.84576</td>
<td>1.000</td>
</tr>
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<tr>
<td></td>
<td>3.00</td>
<td>2.00</td>
<td>1.84576</td>
<td>.843</td>
</tr>
</tbody>
</table>

DIR=Difference in IR ROM, DER=Difference in ER ROM, Group1=control, Group2=Static, and Group3=PNF
Conclusion: A significant effect was found (Lambda (6,98) = .606, p < .001). Follow-up univariate ANOVAs indicated that 1) IR ROM was significantly improved by stretching (F (2, 51) = 8.194, p = 0.001). Follow up Tukey’s HSD indicated that IR ROM increased significantly from control to static stretching M = 3.61 ± 1.49, and from control to PNF stretching M = 6.00 ± 1.49. There was no significant difference from static M = 3.61 ± 1.49 to PNF stretching M = 6.00 ± 1.49. Follow-up univariate ANOVAs indicated that 2) ER ROM was also significantly improved by stretching (F (2,51) = 7.400, p = 0.002). Follow up Tukey’s HSD indicated that ER ROM increased significantly from control to static stretching M = 4.06 ± 1.21, and from control to PNF stretching M = 4.00 ± 1.21. There was no significant difference from static stretching M = 4.06 ± 1.21 to PNF stretching M = 4.00 ± 1.21.
Additional Finding

In addition to the hypotheses testing the researcher also examined the relationship between grade of the baseball players and throwing velocity. The means for throwing velocity by grade of the baseball players and result was shown in Table 10, 11 and 12.

**Table 10:** Throwing velocity by grade of the baseball players

<table>
<thead>
<tr>
<th>Grade</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
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<tbody>
<tr>
<td>9.00</td>
<td>21</td>
<td>63.5810</td>
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<td>1.02881</td>
<td>54.10</td>
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<td>.81859</td>
<td>60.80</td>
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<tr>
<td>11.00</td>
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</tr>
<tr>
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<td>8.70280</td>
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<td>64.50</td>
<td>81.10</td>
</tr>
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<td>5.45490</td>
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<td>54.10</td>
<td>81.10</td>
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</table>

**Table 11:** ANOVA

<table>
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<th>F</th>
<th>Sig.</th>
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<td>Within Groups</td>
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<td></td>
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<tr>
<td>Total</td>
<td>53</td>
<td>1577.064</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 12:** Multiple Comparisons

<table>
<thead>
<tr>
<th>(I) Grade</th>
<th>(J) Grade</th>
<th>Mean Difference (I−J)</th>
<th>Std. Error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
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<td>1.49677</td>
<td>.184</td>
</tr>
<tr>
<td>10.00</td>
<td>11.00</td>
<td>-5.58571(*)</td>
<td>1.85651</td>
<td>.021</td>
</tr>
<tr>
<td>11.00</td>
<td>12.00</td>
<td>-9.35238(*)</td>
<td>2.15707</td>
<td>.000</td>
</tr>
<tr>
<td>10.00</td>
<td>9.00</td>
<td>3.06905</td>
<td>1.49677</td>
<td>.184</td>
</tr>
<tr>
<td>11.00</td>
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<td>1.90236</td>
<td>.553</td>
</tr>
<tr>
<td>12.00</td>
<td>9.00</td>
<td>-6.28333(*)</td>
<td>2.19665</td>
<td>.030</td>
</tr>
<tr>
<td>11.00</td>
<td>9.00</td>
<td>5.58571(*)</td>
<td>1.85651</td>
<td>.021</td>
</tr>
<tr>
<td>12.00</td>
<td>9.00</td>
<td>9.35238(*)</td>
<td>2.15707</td>
<td>.000</td>
</tr>
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<td>2.51667</td>
<td>1.90236</td>
<td>.553</td>
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<td>12.00</td>
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<td>2.45593</td>
<td>.425</td>
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<td>10.00</td>
<td>6.28333(*)</td>
<td>2.19665</td>
<td>.030</td>
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<td>12.00</td>
<td>11.00</td>
<td>3.76667</td>
<td>2.45593</td>
<td>.425</td>
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</table>
A one way ANOVA was used to determine if the grade of the baseball players had an effect on throwing velocity. A one way ANOVA compared the throwing velocity to the each grade of the baseball players. A significant difference was found among the grade of the baseball players (F (3, 50) = 7.543, p < .001). Tukey’s HSD was used to determine the nature of differences between the grade of the baseball players. This analysis revealed that there is no significant difference between 9th grade and 10th grade (p = .184), 10th grade and 11th grade (p = .553), and 11th and 12th grade (p = .425). However, there were significant difference between 9th and 11th grade (p = .021), 9th and 12th grade (p < .001), and 10th and 12th grade (p = .03).

The researcher also examined the relationship between the dominant hand and throwing velocity. The means for throwing velocity by dominant hand and result was shown in Table 13.

**Table 13:** Means of throwing velocity by dominant hand

<table>
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<tr>
<th>Group Statistics</th>
<th>Arm</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
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<td>12</td>
<td>65.4583</td>
<td>4.90945</td>
<td>1.41723</td>
</tr>
</tbody>
</table>

An independent t test was calculated comparing the mean throwing velocity of right handers versus the mean throwing velocity of left handers. No significant difference was found (t (52) = .801), p = .852). The mean of the throwing velocity of right handers M = 66.89 + 5.61 was not significantly different from the mean of throwing velocity of left handers M = 65.36 + 4.91.
DISCUSSION

To discuss the results of this study the following sections are presented: 1) Discussion of the Results, 2) Conclusion, and 3) Recommendations.

Discussion of Results

Upon investigation of the stretching of internal and external rotators of the shoulder on throwing velocity, it was found that stretching had no significant effect on throwing velocity. There was also no significant difference between static and Proprioceptive Neuromuscular Facilitation (PNF) stretching on internal rotation (IR) and external rotation (ER) active range of motion (AROM). However, it was found that stretching had significant effect on IR and ER AROM compared to control group.

The findings of this study did not support the hypothesis that stretching would differ throwing velocity compared to
control group. There was no significant difference in throwing velocity by each stretching. Recent articles have shown that stretching before explosive activity or competition may decrease force and power,\textsuperscript{3-8} by approximately 2\% to 5\% along with explosiveness of the movement.\textsuperscript{6} There was a difference in research outcomes between stretching the shoulder and lower extremities. The reason of the different outcome could be because throwing involves both upper and lower extremities whereas studies regarding the relationship between lower extremity stretching and force production requires only the lower extremities.

This research also rejected the hypotheses that the AROM for (1) IR and (2) ER will be different between PNF and static stretching. Although some studies show that the PNF technique is more effective than traditional static stretching to improve ROM or musculature flexibility,\textsuperscript{16,17} there was no significant difference found in AROM between PNF and static stretching in this study. However, the research supported the hypothesis that shoulder IR and ER AROM will be different after
both static and PNF stretching compared to control group. There was a significant difference in IR and ER AROM after both static and PNF stretching compared to control group.

The findings in this study could be limited due to the use of only eighteen high school baseball players because they have fewer years of experience. Their throwing mechanics might not be consistent compared to college or professional players. The subjects might not have provided their best effort during the contraction phase of the stretching, and when throwing because they were afraid of injury to their throwing shoulder. Alternatively, subjects were not ready to deliver maximum fastball during the first few weeks of the trial because this study started with beginning of the pre-season practice.

**Conclusion**

The findings of this study suggest that stretching for shoulder internal and external rotators stretching do not affect throwing velocity but shoulder stretching increases the active range of motion for internal and external rotation. The
grade they are in affects the subject’s throwing velocity.

Throwing velocity in the upper grades was higher than the lower grades. This could be due to the age, poor throwing mechanics or fewer years of experience in younger baseball players. Throwing velocity of right handers was not significantly different from the mean of throwing velocity of left handers.

Recommendations

This study showed that static and PNF stretching do not affect throwing velocity but both stretching protocols increased both internal and external rotation active range of motion. Therefore, shoulder stretching before practices or games is effective without decreasing in throwing velocity. For the future studies, it is recommended to use the same methods with different levels of baseball players, such as college or professional levels. Another suggestion would be to conduct the experiment in-season or when subjects feel their throwing shoulder is comfortable. This study was conducted at the beginning of the preseason, so some subjects might not be
ready to deliver their maximum fastball during the trial. High school baseball players were also not familiar with passive static stretching or PNF stretching. It would be worthwhile to conduct the experiment after implementing stretching program into daily routine.
REFERENCES


APPENDICES
APPENDIX A

Review of the Literature
Shoulder static or passive stretching is widely performed before baseball practices or games, especially with pitchers. Baseball players have been taught this as the appropriate way for pre-activity warm-up.\textsuperscript{1} Common stretching practices include ballistic, static, active, Proprioceptive Neuromuscular Facilitation (PNF), and dynamic stretching. It is believed that the benefits of stretching include increases in flexibility and range of motion (ROM). Stretching is one of the techniques which enhance the ROM at a given articulation by changing the extensibility of the muscle and soft tissue that permit movement at that joint.\textsuperscript{2} Many pitchers stretch their shoulder before they pitch to loosen up the shoulder musculature. However, according to study by stretching before explosive activity or competition may decrease force and power\textsuperscript{3-8} by approximately 2\% to 5\%, along with explosiveness of the movement.\textsuperscript{6}

The purpose of this literature review is to: 1) define stretching, 2) identify the functional anatomy of the shoulder and throwing mechanics, 4) determine effective time of
stretching, and 5) measure force production after stretching.

**Stretching**

Stretching is one of the commonly used techniques to warm up the muscle, and to increase ROM and flexibility. Flexibility is defined as the ability to move the joint throughout the ROM.\(^2,9,10\) Inadequate flexibility affects the kinetic chain of the body, which can predispose an athlete to injury.\(^4,11\)

Increased flexibility is considerable for the athlete who needs extreme ROM. However, less flexibility of the muscle provides an effective transmission of force by a better mechanism.\(^9\) Muscle spindles and GTO’s act to protect the muscle from injury. Muscle spindles, located in muscle cells, act as sensors to determine how far and fast a muscle is being stretched. They can also initiate a myotactic stretch reflex when activated. Golgi tendon organs (GTO), located in tendons, also function as a sensor for how much tension is being placed on it. Muscle spindles contract to prevent overstretching of the muscle in the joint, but the GTOs relax the muscle when
it is activated.\textsuperscript{12,13} Mitchell et al explained that joint ROM deficiency can be myogenic (involving active and passive characteristics of the muscle), neurogenic (voluntary and reflex control), joint (including the physical structures of the articulation), or connective tissue. They mentioned stretching attempts to affect the first two components, the myogenically and neurologically caused limitation.\textsuperscript{14}

There are several kinds of stretching techniques: ballistic, static and PNF stretching. Ballistic stretching is defined as the quick, jerking motion which theoretically exceeds the extensibility restriction of the muscle in an uncontrolled manner.\textsuperscript{10} This paper focuses on static and PNF stretching for their effectiveness. In the baseball environment, these two stretching techniques have been mostly used.\textsuperscript{1}

Static stretching has been used for movement preparation, flexibility training and injury prevention. This technique involves relaxing and passive elongation of the stretched muscle with no movement.\textsuperscript{3,9-11} Previous studies have shown that
Static stretching is a safe, easiest, and effective technique to improve long-term soft tissue adaptations that enhance flexibility, reduce muscle soreness, and improve recovery from the practice or competition. Static stretching may also increase blood flow to damaged tissue and promote collagen fiber alignment properly during the repair and remodeling phase of the healing process to shorten the rehabilitation time.\textsuperscript{3,9,11,15}

Some studies show that the PNF technique is more effective than traditional static stretching to improve ROM or musculature flexibility.\textsuperscript{16,17} There are seven different techniques in PNF stretching. These are rhythmic initiation, rhythmic-stabilization, repeated-contraction, slow-reversal, slow-reversal-hold, contract-relax, and hold-relax. In PNF stretching, an opposing muscle is shortened by contraction to place the target muscle on stretch, followed by the target muscle contracting statically. Depending on the joint, one repetition of PNF often enables an increased ROM with an anticipated change between three and nine degrees.\textsuperscript{17} Goldman’s
study compared the effectiveness of PNF shoulder IR stretching and posterior glenohumeral joint mobilization for improving posterior shoulder mobility of professional baseball players. They utilized three sets of PNF hold-relax IR stretching. The results showed that PNF stretching produced an acute increase in IR ROM and decreasing posterior shoulder tightness.18

Functional Anatomy of the Shoulder

The shoulder is allowed three degrees of freedom and reinforced for stabilization by musculature and ligamentous tissues. The shoulder complex consists of four joints or articulations: the sternoclavicular joint, the acromioclavicular joint, the glenohumeral joint, and the scapulothrocic articulation.19,20

The sternoclavicular joint is located at the proximal end of the clavicle, which articulates with the sternum.19-21 The sternoclavicular joint allows 30° to 35° of upward rotation, 35° of combined anterior and posterior movement, and 45° to 50° of rotation around its long axis.21 The distal end of the
clavicle and acromion process of the scapula form the acromioclavicular joint. This joint permits 20° to 30° of ROM in the vertical, horizontal and frontal planes. The glenohumeral joint consists of the large articulation surface of the humeral head and the small surface of the glenoid fossa. Only 25% to 30% of the large diameter of the humeral head is in contact with the small diameter of the glenoid fossa. The scapulothoracic articulation, not a true joint, represents a space between the convex surface of the posterior thorax and the concave surface of the anterior scapula. This articulation, which plays an important role in stability and mobility, permits increased shoulder ROM beyond the 120° offered solely by the glenohumeral joint. Also scapulo-humeral rhythm is important to consider for the shoulder movement. In the first 30° of shoulder abduction there is no scapular movement. From 30° to 90°, the humerus elevates 2° for every 1° of scapular abduction and upward rotation. From 90° to maximum shoulder abduction, 1° of scapular abduction and upward rotation occurs for every 1° of humeral
The humerus is the largest and longest bone in the upper extremity. Three rotator cuff muscles, the supraspinatus, infraspinatus and teres minor, are inserted on the greater tubercle of the proximal humerus. The subscapularis, the fourth rotator cuff muscle, inserts on the lesser tubercle on the humerus. The scapula, a large, thin, triangular shaped bone, is located on the posterolateral aspect of the thorax, and sits between ribs 2 and 7. It mainly serves as a site of muscle attachment, including the rotator cuff (supraspinatus, infraspinatus, teres minor, subscapularis), scapular rotators (levator scapulae, trapezius, serratus anterior, rhomboid major and minor), deltoid, pectoralis minor, short head of the biceps brachii, and teres major muscles. The clavicle is the only bone that connects the trunk to the shoulder girdle via the acromioclavicular joint distally and sternoclavicular joint proximally. The distal flat one third of the clavicle serves as a muscle and ligament attachment point, and the proximal tubular one third of the clavicle permits axial
loading. The middle one third is the place where the predominance of fractures occurs because it is the thinnest and weakest part of the clavicle.\textsuperscript{21}

The internal rotators and external rotators of the shoulder play an important role in providing dynamic stability and mobility for the glenohumeral joint, especially for the athletes who use repetitive overhead movement.\textsuperscript{22} Baseball players, especially pitchers, tend to lose ROM for internal rotation (IR) of the shoulder and gain ROM for external rotation (ER) at $90^\circ$ of shoulder abduction from throwing mechanics. In the study of Wilk et al, they introduced study of Brown et al and mentioned that professional pitchers showed $141^\circ \pm 15^\circ$ of shoulder ER, approximately $9^\circ$ more than the non-throwing shoulder, and about $9^\circ$ greater than the throwing shoulder of field players measured at $90^\circ$ of abduction. Wilk et al also showed the study of Bigliani et al, average ER ROM at $90^\circ$ of shoulder abduction was $118^\circ$ (range between $95^\circ$ and $145^\circ$) in pitchers, whereas average ROM of the dominant shoulder in field players was $108^\circ$ (range between $80^\circ$ and $105^\circ$). Ongoing study
of Wilk and Arrigo regards to range of shoulder motion in 372 professional baseball players, similar to study of Bigliani et al, they have noted that pitchers show an average of 129.9° ± 10° of ER and 62.6° ± 9° of IR when passive ROM was measured at 90° of abduction of the shoulder. Total motion of the shoulder (total ROM of ER and IR) in the throwing shoulder is equal (within 5°) when compared with the non-throwing shoulder.23

Throwing Mechanics

Proper coordination of the muscles and biomechanics of the upper extremity is important to produce sufficient force during throwing mechanics.24 To deliver a fast ball, it depends on the acceleration of the upper extremity and the distance that the extremity travels. For example, the velocity of the hand must be 90 mph at the time of release for a baseball to travel 90 mph.25 Maximum throwing velocity potential is generated by optimal throwing mechanics.26

Throwing mechanics consists of 5 phases: Wind-up, cocking, acceleration, deceleration, and follow-through
phases. Each phase has certain period of time from one another.

**Wind-up Phase:** The wind-up phase starts from the first movement of the throwing to the ball leaves the opposite hand of the glove.\(^{20}\) The cocking phase starts from the ball leaves the opposite hand of the glove to the point at maximal shoulder ER.\(^{19,20}\) During this phase, the shoulder establishes an approximately 90° abduction, 30° horizontal extension, 90°-120° of ER when the contralateral foot contact to begin delivery the trunk rotates forward, and produce a 165° to 180° of maximal shoulder ER.\(^{19,24,27}\) The acceleration phase is defined as the time period between the point of maximal shoulder ER and rapid release and acceleration of the ball. When the ball is released between 40° and 60° of ER, the shoulder is internally rotated explosively. Greater shoulder ER causes a stretch of the internal rotator muscle permitting energy to be stored and creating greater ROM of the IR in this phase.\(^{28}\) In the deceleration phase, the most violent muscle contraction and forces are applied to the shoulder, which occurs following ball release. The shoulder muscles resist shoulder distraction, to
slow arm rotation, oppose anterior subluxation forces and aids to decelerate the adducting shoulder in this phase. 

Although a good follow-through is often overlooked and cannot improve the throw directly, it is important for minimizing the risk of injury. A good mechanism of the follow-through is to have the larger parts of the body help dissipate the energy in the throwing arm. The throwing arm should have a long follow through path, permitting the energy to be dissipated over a longer time to reduce the required deceleration force. The correct mechanics of the follow-through include that the pitching hand will finish near the side of the opposite leg.

The rotator cuff and the scapular rotator muscles provide the dynamic stabilization for the glenohumeral joint. The scapular rotator muscles include the levator scapulae, the rhomboids, the trapezius, and the serratus anterior. These muscles stabilize the glenohumeral joint dynamically by placing the scapula in the plane of movement with the arm to maintain maximum static stability.

**Cocking phase**: During cocking phase and the entire
pitching sequence, the dynamic stabilizers of the shoulder joint (the rotator cuff muscles) serve an important role in keeping the humeral head in a centralized position in the glenoid.\textsuperscript{19,27,29} The capsule and ligaments surrounding the shoulder joint must be loose to establish the extreme ROM required to throw a baseball while the dynamic stabilizers are required to provide greater dynamic stability throughout the entire pitching motion.\textsuperscript{27,29}

The dynamic stabilizers function primarily to prevent anterior and upward translation of the humeral head during this phase. The teres minor and infraspinatus muscle limit the anterior translation of the humeral head over the glenoid labrum. While the arm is elevated, during the cocking and acceleration phases, the supraspinatus applies a compressive force and the other 3 rotator cuff muscles apply a downward force which prevent superior translation of the humeral head. During arm elevation, a superior shear force is produced by the middle deltoid muscle on the humeral head which is counterbalanced by the weight of the arm and downward pull of
the infraspinatus, teres minor and subscapularis muscles.\textsuperscript{29} Durall et al also stated that the combined contribution of the proximal portion of the subscapularis and infraspinatus (superior to the center of rotation of the glenohumeral axis) is even to the contribution of the arm elevation by the supraspinatus. They reported that between 0° and 60° abduction, the contribution of the infraspinatus and subscapularis was greatest.\textsuperscript{29} Subscapularis activity increases during the late cocking phase as a protective mechanism and decelerating the ER.\textsuperscript{19}

The internal rotator muscles (anterior deltoid, teres major, pectoralis major, subscapularis and latissimus dorsi muscles) are contracted eccentrically and stretched elastically to decrease the shoulder ER speed.\textsuperscript{19} The subscapularis is contracted eccentrically to protect anterior structures in the joint which are stressed with ER at the conjunction with the pectoralis major and latissimus dorsi muscles.\textsuperscript{25} The shoulder girdle muscles (serratus anterior, levator scapulae, trapezius, pectoralis minor and rhomboids)
also are critical in this phase. When serratus anterior provides stabilization and protraction to the scapula, it is most active. The muscles activated oppositely against the scapular motion produced by the serratus anterior, namely, the middle trapezius and rhomboids, have also shown to be active. During the late cocking phase, the serratus anterior muscle plays an important role in providing upward rotation and protraction of the scapula, and allows anterior scapular movement by horizontally adducting the humerus. At this time, the elbow is flexed to approximately 90° normally, and the wrist is extended slightly. Forearm flexor and pronator muscles, which originate from the medial epicondyle of the elbow, contract to help elbow stabilization. Maximum elbow flexion from 80° to 90° is established approximately 30 milliseconds before the maximal ER of the shoulder. This phase is ended when the shoulder is positioned at horizontal extension, and 160° of ER.

Acceleration phase: During Acceleration phase, the triceps muscle contracts early and the pectoralis major,
latissimus dorsi, teres major, serratus anterior and subscapularis are the muscles capable of producing a great amount of rotational force to accelerate the shoulder in the late stage of this phase.\textsuperscript{25,27} When the shoulder is internally rotated, elbow flexion occurs from 90° to about 120°. Thirty to 40 milliseconds before ball release, the elbow extends quickly to a point of 25° of flexion.\textsuperscript{24} A pitcher is required a short delay between the initiation of the elbow extension and shoulder IR to throw correctly and efficiently. This permits the throwers to decrease the rotational resistance of the arm about its longitudinal axis, therefore allowing greater velocity of shoulder IR to be produced. Andrew et al stated that EMG shows the subscapularis muscle is most active among shoulder internal rotators, followed by the pectoralis major and the latissimus dorsi muscles.\textsuperscript{19} Wrist flexion occurs from an extension to neutral position 20 milliseconds before ball release, and wrist flexion over the neutral position does not occur until the ball is released.\textsuperscript{24} During this phase of pitching, wrist flexors (flexor carpi ulnaris, flexor carpi
radialis and flexor digitorum) have been shown to be activated. Radioulnar pronation starts 10 milliseconds before ball release, up to approximately 90° when the ball is released.

Deceleration phase: In the deceleration phase of the throwing, the supraspinatus, teres major and minor, latissimus dorsi, posterior deltoïd and infraspinatus resists shoulder distraction, to slow arm rotation and oppose anterior subluxation forces. Activation of the teres major, latissimus dorsi, and posterior deltoïd also aids to decelerate the abducting shoulder in this phase. Powers mentioned that the greatest activity of the posterior cuff muscles (the supraspinatus, infraspinatus and teres minor) occurs during the deceleration phase in EMG analysis. A large amount of eccentric force output of the posterior rotator cuff muscle is needed for high-speed deceleration of the arm because these internal rotators/adductors accelerate the shoulder forcefully. The teres minor muscle has shown the highest activity among the all the glenohumeral muscles during
the deceleration phase to provide a posterior restraint which may restrict anterior translation, horizontal adduction and shoulder IR of the humeral head.\textsuperscript{19}

Powers mentioned that the ratio of shoulder internal and external rotator strength in major league baseball players was 3:2, and significant positive correlation was observed between throwing velocity and external strength in healthy professional baseball players. Powers also mentioned Hinton’s study which found a lower ratio in greater internal rotational strength in the dominant arm while there was no difference in external rotational strength.\textsuperscript{25,30} Ramsi et al have reported a 3:2 ratio regarding the appropriate strength ratio between IR and ER in overhead athletes. However, Magnussen\textsuperscript{31} found a 1:1 ratio of IR and ER muscle strength in master level competitive swimmers. The appropriate strength ratio of the IR and ER of the shoulder is still a controversy.\textsuperscript{22} To provide scapular stabilization, the lower trapezius, serratus anterior and rhomboid muscles have been shown to be active. The wrist and finger flexor muscles are also highly activated
during this phase. When the forearm pronates, the pronator teres muscle is quite active, and the biceps and supinator muscles are also contracted eccentrically against the deceleration of the rapid forearm pronation. The wrist and finger extensor muscles, in addition, have shown low to moderate activity, and may have been contracting eccentrically to reduce the speed of the flexing wrist and fingers.\textsuperscript{19}

**Follow through phase**: In the follow-through phase, the posterior shoulder muscles still continue to be fired eccentrically throughout the follow through to decelerate the shoulder which is horizontally adducted in this phase. Joint force torques of the shoulder and elbow produced during the follow through phase are generally lower when compared to the deceleration phase. In this phase, the serratus anterior muscle contracts either concentrically or isometrically, and performs the highest activity of all scapular rotators, while the middle trapezius and rhomboid muscles are contracted eccentrically to decrease scapular protraction speed. Andrew et al mentioned that there is low to moderate activity in the
wrist and finger extensor muscles during the follow through, indicating that they are contracted eccentrically to decelerate the flexing wrist.\textsuperscript{19}

Effective Time of Stretching

Stretching is a widely used technique by health care providers for relaxing and elongating a muscle to increase ROM and prevent injury. However, few studies have explained the exact optimal duration time of stretching. Some studies showed the duration range of static stretching to increase flexibility to be between 15 to 60 seconds. Bandy and Irion demonstrated three different kinds of hamstring stretching duration, 15 seconds, 30 seconds and 60 seconds to examine the length of time to obtain maximal flexibility. Their study showed that people who stretched 30 seconds and 60 seconds showed greater effects than those who stretched 15 seconds and in the control group. They concluded that the most effective duration is 30 seconds and 15 seconds stretching is not effective.\textsuperscript{10} Provance et al demonstrated similar study
finding to Bandy and Irion, they also concluded that 30 seconds of stretching is an effective duration to increase hamstring flexibility.\textsuperscript{32} Ford and McChesney examined the duration of maintained hamstring ROM by applying three different stretching techniques (static(SS), contract-relax, agonist contract(CRAC) and active control(AC)). They measured pre- and post-treatment active knee extension ROM at 0, 3, 7, 12, 18, and 25 minutes. This study showed that those three stretching techniques increased ROM but there was no difference among the three. They concluded that increased ROM after stretching can last for at least 25 minutes.\textsuperscript{4}

**Force Production after Stretching**

Recent research papers have examined the relationship between static stretching and injury prevention. They revealed that static stretching before the exercises is not related to reduction of injury. Actually, stretching before explosive activity or competition may decrease force and power\textsuperscript{3-8} by approximately 2\% to 5\%, along with explosiveness of the
movement. Although acute episodes of stretching decreases power output, long-term stretching enhances performance and improves both power and force when performed consistently for several weeks. Decreased force production during increasing ROM may be caused by neuromuscular factors such as alteration of motor control strategies and mechanical factors such as muscle stiffness changes in the muscle-tendon structures. Skeletal muscle and muscle spindles are able to alter their mechanical tension after a contraction or stretch. Muscle spindle activity relates to muscle stiffness and increased ROM due to acute stretching, and has been shown to be responsible for decreased muscle tension and stiffness. Marek et al conducted a study to examine the relationship of static and PNF stretching, and power output. They measured peak torque, mean power output, active and passive ROM of the knee, electromyographic (EMG) amplitude and mechanomyographic (MMG) amplitude. The result showed that increased ROM was observed along with decreases in peak torque and mean power output after both static and PNF stretching. After 15 min of recovery from
the stretching, most of the reduction of muscular force producing capacity was attributed to intrinsic mechanical factors of the muscle-tendon unit rather than neural properties. They mentioned that the main mechanism of decreased force production caused by stretching is related to a decrease in stiffness of the muscle-tendon unit which may change the length-tension relationship of the muscle fibers. They also said other studies explained that force production decrease may be caused by neural factors such as decreased motor unit excitement, firing frequency, and/or alternation of reflex sensitivity.\textsuperscript{5} Papadopoulos suggested that moderate stretching duration must be used to achieve strength and power improvement, but stretching should be decreased when the goal is maximal motor unit excitement.\textsuperscript{8}

**Summary**

Shoulder static or passive stretching is widely performed before baseball practices or games, especially with pitchers to loosen up the muscle, to increase ROM and
flexibility, and baseball players have been taught as the appropriate way for pre-activity warm-up.1 Flexibility is defined as the ability to move the joint throughout the ROM.2,9,10 Inadequate flexibility can adversely affect the component motions of the kinetic chain, which can contribute to injury susceptibility.11 Stretching before explosive activity or competition may decrease force and power by approximately 2% to 5%, along with explosiveness of the movement.3-8 Although long term stretching after exercise increases ROM and flexibility, and provides benefits for injury prevention, short term stretching has not been shown to prevent injury and does not last for long gained ROM.7,8 Proper fastball pitching technique to produce sufficient force requires proper coordination of the muscles, biomechanics of the upper extremity, acceleration of the upper extremity and the distance that the extremity travels.10,24 Maximum pitching velocity potential is generated by optimal pitching mechanics.26 Duration of the stretching is still controversial but in the study of Bandy and Irion, ROM gained
by stretching the hamstrings for 30 sec and 60 sec was greater than stretching for 15 sec. They concluded that 30 sec of stretching is most effective. Recent studies have shown that stretching before exercise actually decreases force and power caused by either neuromuscular or mechanical factors. Papadopoulos suggested that moderate stretching duration must be used to achieve strength and power improvement, but stretching should be decreased when the goal is maximal motor unit excitation.
APPENDIX B

The Problem
Statement of the Problem

Stretching is commonly used in baseball, especially in pitchers, to warm up the muscle and to increase ROM and flexibility. Flexibility is defined as the ability to move the joint throughout the ROM.\textsuperscript{2,9,10} Inadequate flexibility can adversely affect the component motions of the kinetic chain, which can contribute to injury susceptibility.\textsuperscript{11} However, recent studies show that power output actually decreases after stretching. Stretching before explosive activity or competition may decrease force and power\textsuperscript{3-8} by approximately 2\% to 5\%, along with explosiveness of the movement.\textsuperscript{6} The purpose of this study is to determine if the increased range of motion caused by two types of stretching induces difference in throwing velocity of high school baseball players.

Definition of Terms

The following terms have been operationally defined for the purpose of this study:

1. Flexibility - the ability to move the joint throughout the
2. Ballistic stretching – the quick, jerking motion which theoretically exceeds the extensibility restriction of the muscle in an uncontrolled manner.\textsuperscript{10}

3. Static Stretching – involves relaxing and passive elongation of the stretched muscle with no movement.\textsuperscript{3,9-11}

4. Proprioceptive Neuromuscular Facilitation (PNF) Stretching – an opposing muscle is shortened by contraction to place the target muscle on stretch, followed by the target muscle contracting statically.\textsuperscript{17}

5. Scapulo-humeral rhythm – In the first 30° of shoulder abduction there is no scapular movement. From 30° to 90°, the humerus elevates 2° for every 1° of scapular abduction and upward rotation. From 90° to maximum shoulder abduction, 1° of scapular abduction and upward rotation occurs for every 2° of humeral elevation.\textsuperscript{20,21}

\textbf{Basic Assumptions}

The following are the basic assumptions of this study:
1. The subjects provided their best effort during the contraction phase of the two types of stretching, and when throwing.

2. The STALKER Sports speed gun was calibrated properly and was accurate when used.

3. The goniometer is a valid and reliable tool to measure ROM.

**Limitations of the Study**

The following are the possible limitations regarding the study:

1. The subjects are collected from the baseball team at a PIAA class A high school.

2. The use of high school baseball players as they have fewer years of experience, and throwing mechanics might not be consistent compared to college or professional players.

3. Subjects may withdraw resulting in a minimal number of subjects.
4. The study may experience variability due to using both pitchers and position players.

**Significance of the Study**

This study will examine how two types of IR and ER of the shoulder stretching, static and PNF stretching affect to throwing velocity in baseball players. It is widely believed that to provide stretching before the activity is beneficial to loosen up the muscle, show the best performance, increase ROM and prevent injuries. The goal of stretching is to increase the length of the musculotendinous unit for joint flexibility and to prevent injuries. Static stretching and PNF stretching have been used to gain ROM of the joint. However, recent studies regarding stretching showed the evidence that power output actually decreases after stretching. Long term stretching after exercise increases flexibility and ROM but short term stretching has not been shown to prevent injury. Also gained ROM does not last for a long period of time. The question is, from the recent studies, does stretching differ power output
and throwing velocity? How does gained shoulder ER and IR ROM affect on the throwing velocity? This study will help athletic trainers to decide stretching prior to the activity is effective to increase baseball players’ performance.
APPENDIX C

Additional Methods
APPENDIX C1

Informed Consent Form
Informed Consent Form

Masanao Fujimoto, a Graduate Assistant Athletic Training Student at California University of Pennsylvania, has requested my child’s participation in a research study. The title of the research is “The Relationship between Shoulder Stretching and Throwing Velocity in High School Baseball Players.” I have been informed the purpose of study is to examine baseball pitching speed will be different by different kinds of stretching.

My child’s participation includes regular warm up with the team, throw 10 times as fast as they can, three different days. Two times they will have their throwing shoulder stretched by the researcher, prior to throwing. The other time they will not be stretched by the researcher prior to throwing. There will be one week in between each session. Each session should not be longer than 30 minutes.

The stretching techniques included static stretching and PNF stretching of the external and internal rotators of the shoulder muscles. Static Stretching will be done three times and held for 30 seconds. PNF stretching will be done for three times, each time consist of holding for 6 seconds in stretching position followed by 10 seconds of shoulder contraction against researcher’s resistance. The subjects have ten second intervals between the stretching for the relaxation.

I understand there are predictable risks or discomforts to my child if I agree to have them participate in the study. The possible risks and/or discomforts include muscle soreness from throwing or stretching their shoulder more than they are used to. If soreness occurs, it should subside within three to four days. The researcher will make ice bags available each day. For more serious injury, the researcher is certified in first aid and CPR/AED, and proper medical attention will be provided following the California Area High School emergency
action plan.

There are no available alternative procedures for this study. The effective date of the approval of the study is 1-28-2008 and the expiration date is 1-27-2009.

I understand that the benefits of my child’s participation in the research will be to help examine if stretching of the shoulder external and internal rotators muscle decreases throwing velocity. For this case, the result of this study helps to reconsider shoulder pre-practice stretching.

I understand that the results of the research study may be published, but my child’s name will not be released in public. To maintain confidentiality of my records, Masanao Fujimoto will maintain all documents in a secure location where only the student researcher and research advisor can access them.

I have been informed that any questions regarding this research study or my child’s participation before or after my consent will be answered by Masanao Fujimoto, FUJ2659@cup.edu, 532 Rear 3rd Street, Californian PA 15419, (812) 841-3059.

I have read the above information. The nature, demands, risks, and benefits of the study have been explained to me and I understand that I or my child may withdraw consent and discontinue participation at any time without penalty.

Parent signature ____________________________ Date __________

Student Signature ________________________ Date ______ ______

I prove that I have explained to the above individual the purpose, the benefits, and possible risks related to participation, and have answered any questions for this study. I provided to the parent and participant a copy of this signed consent form at their request.
Researcher’s
Signature___________________________ Date__________

Approved by the California University of Pennsylvania Institutional Review Board.
APPENDIX C2

Child Assent Form
Child Assent Form

I, ______________________, understand that my parents agreed to allow me to participate in a study regarding stretching of my shoulder and measurement of maximum throwing velocity under the direction of Masanao Fujimoto.

I have been informed that I will warm-up and get two types of stretching. My shoulder range of motion will be measured before and after stretching, and after 10 maximum throws of a baseball.

I have been informed that there might be a risk of shoulder musculature soreness after the experiment in this study. I will be offered a bag of ice when I am finished throwing at my request.

I have been explained that participation for this study is not mandatory, and that I may withdraw from participation at any time without penalty or loss of benefit to myself.

Student’s Signature: ______________________ Date:______

Approved by the California University of Pennsylvania IRB
APPENDIX C3

Demographic Sheet and Score Sheet
Demographic Information

1. Grade (circle the number):  9  10  11  12

2. Throwing arm (circle one): Right  Left

3. Injury to throwing arm in last year?  Yes  No

   If yes, what kinds of injury did you have and when was it?

   ________________________________________________________________

   How long were you out from the practice because of the injury?

   ________________________________________________________________

   Do you currently have shoulder pain with throwing?  Yes  No

4. Position of play. Please list in order of most to least played.

   ________________________________________________________________

   ________________________________________________________________

5. How many years have you played baseball?  ____ Years
6. Do you usually stretch prior to practice?  Yes  No

If yes, what kinds of stretch have you getting?

7. Shoulder comfort level pre and post stretching
   (0= most comfort, 10= least comfort)

Day of static stretching:
Pre-stretching: 0 1 2 3 4 5 6 7 8 9 10
Post-stretching: 0 1 2 3 4 5 6 7 8 9 10

Day of PNF stretching:
Pre-stretching: 0 1 2 3 4 5 6 7 8 9 10
Post-stretching: 0 1 2 3 4 5 6 7 8 9 10

Day of Control: 0 1 2 3 4 5 6 7 8 9 10
Score Sheet
Subject’s Name:

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<th>PNF Stretching</th>
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<tr>
<td>Pre - ER (degree)</td>
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<td>Post - IR (degree)</td>
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<tr>
<td>Post - ER (degree)</td>
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<td>Throw 10</td>
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<tr>
<td>Post-IR (degree)</td>
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<td>Post-ER (degree)</td>
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<tr>
<td>Average (mph)</td>
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<tr>
<td>Max. Velocity (mph)</td>
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</table>
APPENDIX C4

STALKER Sport Radar Gun
Specifications

STALKER Sport

PERFORMANCE SPECIFICATIONS
Speed Range 5 - 250 MPH, 8 - 400 KPH
Accuracy + 1 - 0.1 MPH
Target Acquisition Time 0.046 Seconds (Ball Modes)
0.08 Seconds (Vehicle Modes)
Sample Rate 25 Speed Updates per Second
Max. Clocking Distances 4000 Feet - Passenger Car
1500 Feet - Snowmobiles
1000 Feet - Watercraft
200 Feet - Bicycles

MICROWAVE SPECIFICATIONS
Operating Frequency 24.150 GHz (K Band)
Polarization Circular Polarization
3 db Beamwidth 11 Degrees Nominal
Microwave Source Gunn-Effect Diode
Receive Type Schottky Barrier Mixer Diode
Power Output 15 Milliwatts Nominal

The STALKER SPORT Complies with Part 15 and Part 90.101 of the FCC rules. FCC ID #BEDCM1003.

GENERAL SPECIFICATIONS
Product Type Stationary Doppler Radar
Computer Processor 40 MHz Motorola 56002 DSP
Display Type Backlighted Liquid Crystal
Operating Temperatures -20F to +120F
Storage Temperatures -40F to +140F

ELECTRICAL SPECIFICATIONS
Battery Handle 7.5 VDC, 1.5 Ah, Ni-Cad
Corded Handle Input 13.8 VDC (9.0 - 16.0 VDC)
Current Requirements Transmitting - 0.68 Amps
(At 7.5 Volts DC) Standby - 0.20 Amps
Sleep Mode - 0.04 Amps

PHYSICAL SPECIFICATIONS
Weight (Battery Handle) 2.5 Pounds
Weight (Corded Handle) 2.2 Pounds
Dimensions 9.25" H x 3.5" W x 10.2" L
Housing Material High Impact Polycarbonate

WARRANTY
On Radar Gun 2 Years, Parts and Labor
On Batteries 90 Days Replacement

SERIAL COMMUNICATIONS PROTOCOL
A Display Handle or Corded Interface Handle is required for data communications to speed display boards, computers, and other electronic devices. The data connector is on the bottom of these handles. The display handle requires that the radar gun be powered through the data connector. The corded interface handle includes a cigar lighter plug for powering the radar gun.

Connector on Handles 3 Pin Switchcraft TA3ML
Mating Connector Switchcraft TA3FL
Pin Order Pin 1 - Data
Pin 2 - 12 VDC Power
Pin 3 - Ground
Data Type TTL Format
-5V for Logic High
0V for Logic Low
BAUD Rate 1200 BAUD
Data Format 8 Data Bits
No Parity
2 Stop Bits

Data is sent in packets of four ASCII characters followed by a carriage return. A new data word is sent every time the speed changes (up to 25 samples per second) and/or every 1/3 of a second if the speed remains the same.

Example for 59.8 MPH (Vehicle Mode with Tenth Units)

Data Byte 1, ASCII 0
Data Byte 2, ASCII 5
Data Byte 3, ASCII 9
Data Byte 4, ASCII B
Data Byte 5, ASCII CR

Example for 105 MPH (Ball Mode with Whole Units)

Data Byte 1, ASCII 1
Data Byte 2, ASCII 0
Data Byte 3, ASCII 5
Data Byte 4, ASCII : (Colon)
Data Byte 5, ASCII CR

Peak Mode - If Peak Hold is ON, the speed information transmitted will be only the peak speeds. With Peak Hold OFF, the data will be based on the continuously updated speed information.
APPENDIX C5

Institutional Review Board
PROTOCOL for Research Involving Human Subjects

Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects

(Reference IRB Policies and Procedures for clarification)

Project Title: THE RELATIONSHIP BETWEEN SHOULDER STRETCHING AND THROWN VELOCITY IN HIGH SCHOOL BASEBALL PLAYER

Researcher/Project Director: Masano Fujimoto

Phone #: (812) 841-3859    E-mail Address: FJ2659@cup.edu

Faculty Sponsor (if required): Dr. Bruce D. Barnhart

Department: Health Science and Sport Studies

Project Dates: 1/28/2008 to 1/27/2009

Sponsoring Agency (if applicable):

Project to be Conducted at: California University of Pennsylvania

Project Purpose:  ☒ Thesis    ☐ Research    ☐ Class Project    ☐ Other

Keep a copy of this form for your records.

Required IRB Training

The training requirement can be satisfied by completing the online training session at http://ceg.nci.nih.gov. A copy of your certification of training must be attached to this IRB Protocol. If you have completed the training at an earlier date and have already provided documentation to the California University of Pennsylvania Grants Office, please provide the following:

Previous Project Title: __________________________

Date of Previous IRB Protocol: __________________________
Please attach a typed, detailed summary of your project AND complete items 2 through 6.

1. Provide an overview of your project-proposal describing what you plan to do and how you will go about doing it. Include any hypothesis(ies) or research questions that might be involved and explain how the information you gather will be analyzed. For a complete list of what should be included in your summary, please refer to Appendix B of the IRR Policies and Procedures Manual.

The subjects (N=18) will be baseball players from California Area High School who volunteer. Subjects who have a previous history of injury to the throwing shoulder within one year of the study will be excluded. Demographic information sheet included the questions about the injuries: whether subject had injury within one year of the study, what kind of shoulder injury and date of injury, and subject currently has pain with throwing. The subject who was out more than seven days within one year of the study or who has currently pain with throwing will be excluded from this study. Players will be selected regardless of the position they play.

The following instruments will be used for this study: a demographic sheet, the STALKER Sport speed gun which is the name of the device to measure throwing velocity, and a 360 degree goniometer to assess the subject’s active range of motion (ROM). The demographic sheet included information such as year in school, years experience in baseball, throwing arm, position, question regarding injury, current stretching program prior to practice before this study, and the subject’s perception of stretching before and after the stretching protocol.

To conduct the static stretching of the shoulder external and internal rotators (ER and IR respectively), the subject will be placed supine on the table to stabilize the scapula with the shoulder abducted at 90 degrees and the elbow flexed at 90 degrees. The researcher stands on the same side of the stretching shoulder. To stretch the ER, the shoulder is internally rotated to the point where subject feels discomfort, and statically holds in a stretch for 30 seconds. To stretch the IR, the shoulder is externally rotated to the point where subject feels discomfort, and statically holds in a stretch for 30 seconds. This static stretching for both ER and IR will be repeated three times. The subjects then have a 10 second intervals between the stretching for the relaxation. The order of stretching is not randomized, therefore ER stretching will be performed followed by IR.

To conduct the Proprioceptive Neuromuscular Facilitation (PNF) stretching, a hold-relax technique will be used for ER and IR stretching. The subject is placed supine on the table to stabilize the scapula with the shoulder abducted at 90 degrees and the elbow flexed at 90 degrees. The researcher stands on the same side of the stretching shoulder. To perform the ER stretch, the shoulder is internally rotated passively to the point where subject feels discomfort. The position will be held for ten seconds, and then the subject performs a maximum isometric contraction of ER for six seconds against maximum resistance given by the researcher. To perform the IR stretch, the shoulder is externally rotated passively to the point where subject feels discomfort. The position will be held for ten seconds, and then the subject performs a maximum isometric contraction of IR for six seconds against maximum resistance given by the researcher. This stretching procedure for both ER and IR will be repeated three times. The subjects then have ten second intervals between the stretching for the relaxation. The order of stretching is not randomized, therefore ER stretching will be performed followed by IR.

The researcher informs the baseball players at the beginning of the baseball season in January. Volunteers who are interested receive consent forms for both the players and their parents to complete. When athletes schedule for the experiment, the consent forms will be submitted to the researcher and the subjects will be randomly assigned to the group they would be in by picking a number out of a bag. Assigned groups will be: Group 1 (control, static, PNF), Group 2 (control, PNF, static), Group 3 (static, control, PNF), Group 4 (static, PNF, control), Group 5 (PNF, control, static), and Group 6 (PNF, static, control). Three subjects will be assigned to each group. To begin the experiment, the subjects perform their regular warm up with the team. There will be no limitation to what they can do, such as jogging, tossing, sprinting etc. during the warm-up. After the warm up is completed, each subject is called and has their IR and ER AROM measured using the goniometer. Fulcrum of the goniometer is placed on the olecranon process of the elbow, stationary arm is placed parallel to the middle trunk, and moving arm is placed along the ulna. Then the assigned stretching will be provided. After stretching is completed, the subjects have IR and ER AROM measured again, and proceeds to the baseball field and tosses the ball to warm up the shoulder for 10 minutes. Pitchers throw the baseball from the mound to the catcher, a distance of sixty feet and six inches. The field players, to avoid the awkwardness of throwing from the mound, throw the baseball from the field to the catcher. The distance they throw is the same as the pitchers. Then the first ten throws of the fastball will be measured and recorded. After the velocity is recorded, AROM of the throwing shoulder is reassessed and recorded. The subject whose turn is control, has no stretching provided. After the warm up is completed, each subject is called and has their IR and ER AROM measured using the goniometer, and proceeds to the baseball field and tosses the ball to warm up the shoulder for 10 minutes. Then the first ten throws of the fastball will be measured and recorded. After the velocity is recorded, IR and ER AROM of the throwing shoulder is reassessed and recorded. There is a seven day interval between each session.

The following hypotheses will be tested in this study:
1. Shoulder IR and ER ROM will be different after both static and PNF stretching.
2. The average throwing velocity will be different for the static and PNF stretching group compared to the control group.
3. The ROM for (1) IR and (2) ER will be different between PNF and static stretching.

Draft, April 7, 2005
Data will be analyzed using the SPSS statistical software package, version 14.0. All tests of statistical significance used an alpha level of .05.

1. A repeated measure ANOVA will be used to determine if shoulder IR and ER ROM will be different after both static and PNF stretching.

2. A one way ANOVA will be used to determine if the average throwing velocity will be different for the static and PNF stretching group compared to the control group.

3. A MANOVA will be used to determine if the ROM for (1) IR and (2) ER will be different between PNF and static stretching.

4. Section 46.11 of the Federal Regulations state that research proposals involving human subjects must satisfy certain requirements before the IRB can grant approval. You should describe in detail how the following requirements will be satisfied. Be sure to address each area separately.

   a. How will you insure that any risks to subjects are minimized? If there are potential risks, describe what will be done to minimize these risks. If there are risks, describe why the risks to participants are reasonable in relation to the anticipated benefits.

   All subjects will be informed of the foreseeable risks as stated in the informed consent form. All Subjects perform the same warm up. All subjects will have up-to-date physicals, as required by the high school, before they participate this study. Prior history of the injury to the throwing shoulder within a year will be excluded from this study based on the questions in the demographic sheet. The risk of injury due to maximal throwing is no greater than the risk related to participation in their sport. The only foreseeable risk is muscle/joint soreness. The researcher will make ice bags available each day of the experiment. The researcher is certified in first aid and CPR, and proper medical attention will be provided following the California Area High School Emergency Action Plan.

   b. How will you insure that the selection of subjects is equitable? Take into account your purpose(s). Be sure you address research problems involving vulnerable populations such as children, prisoners, pregnant women, mentally disabled persons, and economically or educationally disadvantaged persons. If this is an in-class project describe how you will minimize the possibility that students will feel coerced.

   All baseball players at the high school will be allowed to participate with several exceptions. Athletes who have prior history of the injury to their throwing shoulder within one year of the study. The National Athletic Training Association (NATA) defines a minor injury as forcing loss of participation for less than one week, moderate injuries span 8-21 days, and anything beyond 21 days is severe. No punishment of any kind will be given by either the researcher or the coach if they do not wish to participate or finish the study.

   c. How will you obtain informed consent from each participant or the subject’s legally authorized representative and ensure that all consent forms are appropriately documented? Be sure to attach a copy of your consent form to the project summary.

   The researcher will have a meeting, and inform the study and show to the interested subjects what stretches will be done. At this time the informed consent and assent form will be distributed. Students will not be permitted to participate to this study without both forms being signed and turned in.

   d. Show that the research plan makes provisions to monitor the data collected to insure the safety of all subjects. This includes the privacy of subjects’ responses and provisions for maintaining the security and confidentiality of the data.

   All information will be kept in a secure location at the researcher’s residence. Only the researcher will access the records, and the research advisor will see them as needed.

5. Check the appropriate box(es) that describe the subjects you plan to use.

Draft, April 7, 2005
6. Is remuneration involved in your project? □ Yes or ☒ No. If yes, explain here.

7. Is this project part of a grant? □ Yes or ☒ No. If yes, provide the following information:
   Title of the Grant Proposal ____________________________________________
   Name of the Funding Agency __________________________________________
   Dates of the Project Period ____________________________________________

8. Does your project involve the debriefing of those who participated? □ Yes or ☒ No
   If Yes, explain the debriefing process here.

9. If your project involves a questionnaire interview, ensure that it meets the requirements of
Project Director’s Certification
Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research

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Student or Class Research

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ACTION OF REVIEW BOARD (IRB use only)

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. uses appropriate methods to obtain informed, written consent;
3. indicates that the potential benefits of the investigation substantially outweigh the risk involved.
4. provides adequate debriefing of human participants.
5. provides adequate follow-up services to participants who may have incurred physical, mental, or emotional harm.

[ ] Approved [ ] Disapproved

Chairperson, Institutional Review Board

Draft, April 7, 2005

01-25-06

Date
REFERENCES


ABSTRACT

TITLE: The Relationship between Shoulder Stretching and Throwing Velocity in High School Baseball Players

RESEARCHER: Masanao Fujimoto

ADVISOR: Dr. Bruce Barnhart

DATE: May 2008

RESEARCH PROBLEM: Master Thesis

PURPOSE: The purpose of this study was to examine the relationship between shoulder stretching and throwing velocity in high school baseball players.

PROBLEM: Few research studies have been conducted to support the relationship between shoulder stretching and throwing velocity.

METHOD: This study used a quasi-experimental within subject design. Eighteen high school class A baseball players participated in this study. All of the testing was conducted once a week for three weeks for approximately thirty minutes on each subject.

FINDINGS: There was no relationship between shoulder stretching and throwing velocity, however, both static and PNF stretching increased the active range of motion for internal and external rotation compared to the control group. There was no significant difference between static and Proprioceptive Neuromuscular Facilitation stretching on internal rotation and external rotation active range of motion.

CONCLUSION: Stretching for shoulder internal and external rotation before baseball practices or games did not affect the throwing velocity but stretching increased the active range of motion of internal and external rotation.