The Effects of a 15-minute Coaching Session on Shoulder Torque in Novice Baseball Players

A thesis submitted in partial fulfillment of the requirements For the degree of Master of Science in Kinesiology

By

Yuri Newton

December, 2012
The thesis of Yuri Newton is approved:

__________________________________________ Date
Jennifer Romack, Ph.D.

__________________________________________ Date
Konstantinos Vrongistinos, Ph.D.

__________________________________________ Date
Shane Stecyk, Ph.D., Chair

California State University, Northridge
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Abstract

The Effects of a 15-minute Coaching Session on Shoulder Torque in Novice Baseball Players

By

Yuri Newton

Master of Science in Kinesiology,
Biomechanics

Based on many findings of kinetic, kinematic, and temporal variables in baseball pitching, researchers have postulated what are believed to be ideal pitching mechanics, specifically those that encourage better kinetic transfer (kinematic chain) among body segments, thus better distribution of stress on joints to avoid injuries. The primary purpose of this study was to determine if a 15-minute coaching session could make significant differences in timing of pelvic, trunk, and shoulder rotation during baseball pitching. The secondary purpose of this study was to determine if a 15-minute coaching session could make significant differences in maximum shoulder internal torque, ball velocity, and finger velocity. Nine college students’ pitching motions were analyzed and compared before and after a 15-minute coaching session. There were no significant differences in the three temporal parameters (pelvic, trunk, and shoulder rotation) before and after coaching. Maximum shoulder internal torque increased after the coaching session, but the difference was not significant. Finger velocity was the only significant change (P = 0.004) found in this study.
Introduction

Many professional baseball pitchers suffer time loss upper extremity injuries, some of which are career ending. Due to the complexity and velocity of the throwing motion, coaches, athletic trainers, and strength and conditioning coaches continue to be challenged to develop effective injury prevention programs. Continued research in this area is needed to determine relationships between critical elements of the throwing motion, and their effects on injury. Much of the research to this point described kinematic and kinetic elements of the throwing motion (Aguinaldo, Buttermore, & Chambers, 2007; Aguinaldo & Chambers, 2009; Feltner & Dapena, 1989; Fleisig, Dillman, Escamilla, & Andrews, 1995; Guo, Lin, Tsai, Hou, Chen, Yang, Huang, & Liu, 2009; Matsuo, Fleisig, Zheng, & Andrews, 2006; Stodden, Fleisig, McLean, & Andrews, 2005; Werner, Murray, Hawkins, & Gill, 2002). Fleisig, Dillman and Andrews (1989) determined the tensile strength of the ulnar collateral ligament in cadaver elbows and determined that the load on the elbow during pitching is more than the ligaments can handle without damage. Other researchers have identified and measured the sequential joint movements during baseball pitching which include pelvic rotation, torso rotation, shoulder internal rotation, and elbow extension. Some researchers believe that the timing of pelvic rotation is a key factor in understanding the kinetic chain between lower and upper extremities. Therefore, it would be important to investigate an intervention for gaining proper body coordination to distribute extra stress on the body segments and joints to reduce the risk of baseball injuries.
Literature Review

Pitching Phases

Baseball pitching includes six phases of motion: wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through (Figure 1). Body segments and their variables can be analyzed within each phase. The first phase, wind-up, begins when the pitcher raises the front leg and ends at the point of maximum knee height.

6 Phases of Baseball Pitching Motion

![Diagram of baseball pitching phases](image)

Figure 1: The six phases of pitching motion (Fleisig, Barrentine, Zheng, Escamilla, & Andrews, 1999)

The second phase, stride, is the time between the knee-up position to stride foot contact (SFC). Dillman, Fleisig, and Andrews (1993) emphasized the importance of
keeping the trunk as vertical as possible during the stride phase. This position provides
good balance that helps to facilitate an efficient kinetic transfer from the lower
extremities to the upper body (kinetic chain). Also, shoulder positions at SFC have been
reported by multiple studies. Werner et al. (2002) found that the professional baseball
pitchers who had lesser degrees of shoulder abduction at the SFC had reduced elbow
valgus torque. Stodden et al. (2005) found that the subjects who threw faster balls had
significantly less shoulder horizontal adduction at SFC.

The third phase, arm cocking, is defined as the time from SFC to maximum
shoulder external rotation (MER). During this phase, researchers have been drawn to
upper body movements. The magnitude of MER increases as shoulder horizontal
adduction occurs. The MER is believed to be an indicator for risk of shoulder injuries
(Ellenbecker & Mattalino, 1997). However, researchers have reported the critical roles of
pelvis and torso rotation. Before MER, pitchers should reach the maximum pelvis
rotation (Aguinaldo & Chambers, 2009). Additionally, faster average pelvis rotation had
produced faster ball velocities (Stodden, Fleisig, McLean, Lyman, & Andrews, 2001).

The fourth phase, arm acceleration, is the time between MER and ball release
(BR). While the pelvis and torso continue to rotate, the throwing shoulder starts to
internally rotate and extend. Stodden et al. (2001) demonstrated that faster pitchers had a
faster average upper torso rotation in this phase. At BR, there was a correlation found
between increased degrees of trunk tilt forward and increased ball velocity (Stodden et al.,
2005).
During the fifth phase, deceleration, the glenohumeral joint continues to internally rotate and extend, and this phase comes to the end when shoulder internal rotation ends. Although elbow extension is a key factor to increase ball velocity, fully extending the elbow at BR can cause elbow injuries. Therefore, the eccentric contraction of the elbow flexors play an important role in preventing full extension of the elbow at BR and to decelerate the elbow extension after BR (Hong, Chueng, & Roberts, 2001). The sixth and final phase, follow-through, consists of a smooth slow down to the throwing arm, and the rest of the body should complete its rotation naturally. A full-body follow-through is important because this dissipates and distributes the injurious force from the throwing shoulder.

**Baseball Elbow Injuries**

Tullos and King (1973) reported that 50 percent of professional baseball pitchers experienced either elbow or shoulder symptoms which lead to the end of their professional careers. From a biomechanical approach, injury can result from valgus extension overload, a combination of valgus torque and elbow extension in the cocking and acceleration phases of throwing (Whiting & Zernicke, 1998). According to Ellenbecker and Mattalino (1997), baseball pitching produces the greatest valgus torque and angular velocity of all overhead throwing motions; this may be related to the greater incidence of medial elbow injuries in pitchers. The repetitive overhead throwing motion can cause chronic microtrauma of the elbow joint and culminate in a medial (ulnar) collateral ligament (MCL) injury; one of the most frequent baseball injuries to the elbow. Many researchers have approached these throwing injuries through biomechanical kinetic, kinematic, and temporal analyses.
Fleisig and Barrentine (1995) addressed the cause of MCL injury by analyzing the force, torque, and stress on the tissue during baseball pitching. Due to the location and function of the MCL, the anterior bundle receives injurious kinetics from the valgus extension overload and external rotation on the elbow in the windup and cocking phase of throwing. Valgus torque is resisted by a varus torque produced by musculotendinous and periarticular tissues. At MER, the shoulder joint is externally rotated 165° and the elbow is flexed 95°. In contrast to the gratitude of shoulder external rotation, varus torque hits its peak before MER and decreases when shoulder external rotation hits its peak. Elbow flexion torque increases and peaks between MER and ball release. Fleisig et al. (1989) demonstrated in an earlier study that 11 cadaver elbows were tested to determine the ultimate tensile stress of the MCL. The tensile stress was 642 N before failure, which corresponds to 32 N·m of varus torque to resist valgus stress. This means that professional pitchers’ elbow varus torques typically exceed double the load that human ligaments can normally withstand. Additionally, shoulder internal rotation torque is an indicator for elbow valgus torque (Fleisig et al., 1995).

Davies (1992) stated that the upper extremity kinetic chain comprises the musculature and articulations of the trunk, scapulothoracic, scapulohumeral, and distal arm segments. Work in these segments is transmitted to the trunk and spine through a large musculoskeletal surface which results in the production of massive amounts of energy, with each joint in the kinetic chain cumulatively adding its load and serving as a fulcrum for proximal and distal segments. Tissues are at greatest risk for injury in the weakest points in the kinetic chain. Therefore, observing and identifying the weakness in
the kinetic chain would be a key technique for the injury prevention (Strizak, Gleim, Sapega, & Nicholas, 1983).

In 2010, Bushnell, Anz, Noonan, Torry, and Hawkins reported the correlation between maximum pitch velocity and elbow injuries. Although additional factors such as age, experience level, body size, and pithing count may affect the risk of elbow injuries, multiple studies have supported the relationship between faster ball velocities and the higher elbow injury risks (Escamilla, Fleisig, Barrentine, & Andrews, Moorman, 2002; Olsen, Fleisig, Dun, Loftice, & Andrews, 2006). Theoretically, better performer should have more efficient pitching mechanics. Many researchers have tried to find ideal pitching motions using different variables among a variety of skill levels.

**Kinetic and Kinematic Parameters**

Baseball pitching research to date consists of laboratory descriptive studies that have addressed the kinetic and kinematic differences by age, skill levels, and nationalities (Dun, Fleisig, Loftice, Kingsley, Andrews, 2007; Escamilla, Fleisig, Barrentine, Andrews, & Moorman, 2002; Fleisig et al., 1999). Findings from these studies resulted in pitching mechanics guidelines for coaching, conditioning, and injury prevention programs. For example, Stodden et al. (2001) attempted to find the relationship of pelvis and upper torso angles to the XY plane at four different timings (maximum knee height, SFC, MER, and BR) and ball velocity. Angular velocities of both pelvis and upper torso rotation were measured simultaneously and compared to ball velocity. Nineteen elite baseball pitchers were recruited from professional, college, and high school levels. The inclusion criterion was to be able to pitch faster than 33.0 m/s (75 mph) and to have at least 1.8 m/s (4 mph)
of variation in the ball velocity during the pitching trials. There must be greater variance in ball velocity in poorer skilled players due to the inconsistency of their pitching mechanics. These criteria allowed the researchers to filter subjects’ performance levels not by relying on their skill levels.

Stodden et al. (2001) clarified the torso mechanics during the second to forth pitching phases. The upper torso and pelvis were in a closed position at maximum knee height. As pitchers continued through the throwing motion, the pelvis was more open (27 ± 13°) than their upper torso (-19 ± 15°) at SFC. This indicated a definitive delay between the pelvic and upper torso rotation during the cocking phase. At MER the torso “caught up” to the pelvis pelvic and torso orientations were approximately equal. During the acceleration phase, the upper torso continued rotating, while pelvis rotation remained stable.

Stodden et al. (2001) also identified five variables that had significant positive correlations with ball velocity. The variables included pelvis orientation angle and upper torso orientation angle at MER, pelvis orientation angle at BR, average pelvis velocity, and average upper torso velocity during arm acceleration phase. These results suggested that most of the upper torso and pelvic rotations have to occur during arm cocking and arm acceleration phases to maximize the potential contribution of the torso. Training programs that increase upper torso and pelvic rotation velocity may enable baseball pitchers to throw faster.

Werner et al. (2002) also investigated the interaction between kinetic and kinematic variables on elbow valgus torque. They analyzed 40 professional baseball
pitchers and utilized three 120-Hz cameras to take three dimensional coordinate data to obtain 37 kinetic and kinematic parameters. Four of the variables were significantly correlated with elbow valgus torque: 1) shoulder abduction angle at SFC, 2) maximum horizontal adduction angular velocity, 3) elbow angle at peak valgus stress, and 4) peak shoulder external rotation torque. Werner concluded that a pitcher should have limited shoulder abduction at SFC, in order to reduce elbow valgus torque. However, Matsuo et al. (2006) disputed this conclusion.

Matsuo et al. (2006) questioned Werner’s (2002) results, because other literature suggested greater shoulder abstraction at SFC to reduce the risk of the baseball elbow injuries. For example, numerous researchers insisted that sidearm throwers were prone to the elbow injury (Albright, Jokl, Shaw, & Albright 1978; House, 1990; Norwood, Del-Pizzo, Jobe, & Kerlan, 1978). Also Matsuo, Takada, Matsumoto, and Saito (2002) reported the main biomechanical difference between overhand throw and sidearm pitcher is the trunk tilt. Based on these findings, Matsuo et al. (2006) hypothesized that lateral trunk tilt and shoulder abduction influenced elbow valgus torque.

Matsuo et al. (2006) recruited 32 college baseball pitchers for their study, all of which pitched with either overhand or three-quarter delivery styles. Pitchers were analyzed using a four 200-Hz camera three dimensional motion analysis system. They analyzed shoulder abduction and trunk tilt angles at BR instead of shoulder abduction angles at SFC (Werner et al., 2002). The angles at BR might be a better indication of the subjects’ throwing types, because angles at the ball release are dictated by the previous phases in the pitching delivery. Results showed a significant interaction between shoulder abduction and lateral trunk tilt ($p < 0.0001$). There was no significant correlation between
elbow valgus torque and either shoulder abduction or lateral trunk tilt in the regression analysis. However, they found a trend in the relationship between elbow valgus torque and the interaction of shoulder abduction and lateral trunk tilt. Subjects experienced the same amount of elbow valgus torque with a greater abduction angle and increased ipsilateral trunk tilt. Minimum peak valgus torque (61 ± 14 Nm) was produced when the subjects had a combination of 100° of shoulder abduction and 10° of lateral trunk tilt, and maximum peak valgus torque (125 ± 21 Nm) was produced by the combination of 120° of shoulder abduction and 40° of contralateral trunk tilt. To just compare the shoulder abduction angles between minimum and maximum peak valgus torque with this normalized data, less shoulder abduction may cause decreased elbow valgus torque which agrees with the results of Werner. The common research delimitation between Werner and Matsuo was that the researchers forced subjects to pitch with different delivery types than the pitchers normally utilized to compare the different shoulder abduction angles.

Temporal Parameters

One of the biggest findings regarding the relationship between mechanics baseball pitching injuries was the timing of trunk rotation. Using 38 baseball pitchers from four different levels (youth, high school, collegiate, and professional), Aguinaldo et al. (2007) tested degree of trunk rotation, onset time of trunk rotation, and shoulder internal rotation torque. The degree and onset time of the trunk rotation were measured when the separation between upper torso and pelvic rotation reached its maximum.

While there was no significant difference in the magnitudes of trunk rotation (52 ± 8°, $p = .48$) among four different skill levels, they found a significant difference in the
onset of trunk rotation between professionals and the other three skill levels. Although 11 of amateur pitchers had onset before the front-foot contact, the professionals had an average onset of trunk rotation at 34.3 ± 5 % of the pitching cycle. Youth pitchers showed the lowest raw internal rotation torque which was significantly less than collegiate and high school pitchers’ internal rotation torque. Since the ability to produce torque is related to body size the authors normalized internal rotation torque by dividing the raw torque by (height times weight). Professionals exhibited significantly less normalized peak shoulder internal rotation torque than amateur pitchers at all three levels. Thus, later trunk rotation in the pitching cycle can be one of the key factors to reduce elbow valgus torque. This delay may also be important in increasing ball velocity with each pitch as it allows for greater summation of forces.

Aguinaldo et al. (2007) elaborated that the torso, more than half of body mass, should be not rotate the torso until the forces from the lower extremity have been transferred through the pelvis. By rotating the trunk too early in the pitching cycle, it can interrupt the flow of the sequential joint movements which may require the upper extremity to generate more force than otherwise required. Although higher skilled pitchers demonstrated both later trunk rotation and less normalize elbow valgus torque, this does not support a cause-effect relationship.

In one of the more recent studies, Aguinaldo and Chambers (2009) tested 12 kinetic, kinematic, and temporal variables to examine their relationship with elbow valgus torque. A total of 69 adult baseball players recruited from collegiate, minor league, and major league teams. Dependent variables were onset of trunk rotation, trunk rotation angle, trunk tilt, maximum shoulder external rotation, shoulder abduction,
horizontal abduction, maximum elbow flexion, onset of maximum elbow flexion, elbow flexion at peak valgus torque, elbow flexion at ball release, maximum horizontal adduction velocity, and valgus loading rate. Of these 12 measures, five had significant correlations with elbow valgus torque. Remarkably, the positive correlation between maximum shoulder external rotation and elbow valgus torque was contradictory to Werner et al.’s (2002) study, but it was supported by the Fleisig et al. (1995). Those researchers agree that shoulder external rotation torque is the main indicator of the value of elbow valgus torque.

Fleisig et al. (1999) examined kinetic, kinematic, and temporal parameters using a total of 231 subjects who were divided into four different age/skill levels which were youth, high school, college, and professionals. Their results showed that six out of 16 kinematic parameters were significantly different among the four subject groups, and eight of all kinetic parameters were significantly different as well. Although these parameter differences existed, there was no significant difference found in the temporal variables. Because of these findings, Fleisig insisted that the parameter differences were created by the muscle mass and strength differences from mature level of the subjects’ bodies. Also no existence of difference in temporal parameters indicated that youth players were capable to learn the proper pitching mechanics. Thus, Fleisig concluded that best time to work on the mechanics in order to prevent pitching injuries was early in a pitcher’s career. In addition, Fleisig did not find the significant timing differences in both maximum pelvis angular velocity and maximum upper torso angular velocity in the pitching cycle. However, a slight increase in the timing of upper torso angular velocity had shown as the age/skill level increased.
One should use caution when applying Fleisig et al.’s (1999) findings to real pitching mechanics. If a pitcher tried to throw a baseball with following all the significant parameters that are postulated to reduce elbow valgus torque, it would result in less maximum shoulder external rotation, more elbow flexion at peak valgus torque, more elbow flexion at ball release, post front-foot contact onset of trunk rotation, and less elbow valgus loading rate. However, applying these recommendation would decrease performance, specifically, ball velocity because an increase in elbow flexion during the cocking phase leads to a shorter radiiuses of gyrationaround the long axis of humerus and the axis of trunk rotation. These shorter radii of gyration directly reduce both moment inertia and force production (Newton’s Second Law). Biomechanical principles demonstrate that more elbow flexion causes less elbow valgus torque, but it also leads to a decrease in ball velocity. In fact, the subjects who had onset of trunk rotation before front-foot contact had greater ball velocity (33.1 ± 4.1 m/s) than the subjects who had onset of trunk rotation after front-foot contact (31.8 ± 1.6 m/s), even though their difference was not statistically significant. Although the literature demonstrated that trunk/pelvic rotation was a key factor for an efficient kinetic transfer from lower extremities to upper extremities, no study has analyzed training programs that may improve trunk/pelvic rotation timing.

**Statement of Research Problem**

The purpose of this study was to determine if a 15-minute coaching session could affect timing of pelvic, trunk, and shoulder rotation. The secondary purpose of this study was to determine if a 15-minute coaching session can make significant differences in maximum shoulder internal torque, finger velocity, and ball velocity.
<table>
<thead>
<tr>
<th>Variables</th>
<th>Abbreviations</th>
<th>Units</th>
</tr>
</thead>
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<tr>
<td>Maximum Shoulder Internal Torque</td>
<td>MST</td>
<td>Newton meters (Nm)</td>
</tr>
<tr>
<td>Timing of Maximum Pelvic Rotation (%)</td>
<td>MP</td>
<td>Percentage of pitching cycle</td>
</tr>
<tr>
<td>Timing of Maximum Trunk Rotation (%)</td>
<td>MT</td>
<td>Percentage of pitching cycle</td>
</tr>
<tr>
<td>Timing of Maximum Shoulder Rotation (%)</td>
<td>MS</td>
<td>Percentage of pitching cycle</td>
</tr>
<tr>
<td>Finger Velocity</td>
<td>FV</td>
<td>Meters per second (m/s)</td>
</tr>
<tr>
<td>Ball Velocity</td>
<td>BV</td>
<td>Meters per second (m/s)</td>
</tr>
</tbody>
</table>
Methods

Participants

Using a convenient sample, nine healthy undergraduate kinesiology students were recruited for this study by email invitations. Four of the participants were male, and five were female. Three of the participants were left handed and six were right handed. Participants descriptive data are provided in Table 2 (age range: 22 ± 3 yrs, height: 164.7 ± 8.6 cm, mass: 69.7 ± 36.4 kg).

Procedures

This study was conducted in the biomechanics laboratory at California State University, Northridge. After completing PAR-Q (Appendix A) and Subject Information Sheet (Appendix B), participants’ anthropometric measurements were taken. Males were shirtless, and females wore a sport bra. All participants wore a pair of tight fitting spandex shorts and rubber soled shoes.

In order to become more familiar with performing inside a laboratory environment, participants completed a self-determined warm-up using as much time as they needed. Following the warm-up, 39 spherical reflective markers were attached to anatomical landmarks as depicted (Appendix C). Five pitching trials with 90-100% effort were collected from each subject. Then, a 15 minute coaching session was given. Researchers provided verbal cues based on subjects’ pitching form. The primary purpose of verbal cues was to correct common biomechanical errors such as opening the hips too soon, not stepping towards the target, and leading with the upper body. Subjects’ fatigue was determined by verbal feedback from each participant and visual observation of the
researchers in order to limit the possibility of the participants being fatigued during the post-test.

Table 2
Subjects’ Measurements

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<tr>
<th>Participant</th>
<th>Age (yrs)</th>
<th>Height (mm)</th>
<th>Weight (kg)</th>
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<tr>
<td>A</td>
<td>25</td>
<td>1708</td>
<td>72.3</td>
</tr>
<tr>
<td>B</td>
<td>22</td>
<td>1580</td>
<td>52</td>
</tr>
<tr>
<td>C</td>
<td>24</td>
<td>1705</td>
<td>106.1</td>
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<tr>
<td>D</td>
<td>20</td>
<td>1561</td>
<td>63.7</td>
</tr>
<tr>
<td>E</td>
<td>21</td>
<td>1655</td>
<td>59.6</td>
</tr>
<tr>
<td>F</td>
<td>22</td>
<td>1585</td>
<td>54.5</td>
</tr>
<tr>
<td>G</td>
<td>19</td>
<td>1615</td>
<td>66.1</td>
</tr>
<tr>
<td>H</td>
<td>23</td>
<td>1695</td>
<td>71.5</td>
</tr>
<tr>
<td>I</td>
<td>24</td>
<td>1722</td>
<td>81.9</td>
</tr>
<tr>
<td>Mean</td>
<td>22.1</td>
<td>1647.3</td>
<td>69.7</td>
</tr>
</tbody>
</table>

Post-coaching session data was collected immediately after the coaching session, and the procedure was the same as the pre-coaching session. Five pitching trials were recorded again. After the post-test, subjects completed a self-determined cool-down.
Instruments

The kinetic, kinematic, and temporal data was collected with a Vicon Nexus system (Vicon Motion Systems, Oxford, UK), using the full-body Plug-in Gait model. Seven infrared cameras at 240 Hz collected kinematic and temporal data. Two Kistler force plates (9287A and 9287BA) (960 Hz) were integrated with a Vicon Nexus system. The pitching target was approximately the same size as the strike zone (20.7” x 36.5”), and it was located in middle of a baseball practice net 37 feet away.

Data Reduction

Previous studies (Werner, Fleisig, Dillman, & Andrews, 1993; Fleisig et al., 1999; Matsuo et al., 2002) demonstrated, within-subject pitching mechanics to be consistent from trial to trial, therefore, one trial for each participant was selected for analysis. Two or three post coaching trials per subject were selected for analysis due to potential increased variability in the subjects’ pitching mechanics. Modified movement patterns take longer than the study intervention to become automatic and there is increased variability in the movement patterns until the motor learning process is complete. These trials were averaged to represent their kinetic and temporal values of their performance.

Visual 3D was used to calculate maximum shoulder internal torques (MST), and the raw data was presented. Finger velocity (FV) was manually calculated by dividing the distance the finer marker traveled in the two frames before BR by 0.00417 (1/frame rate). A circular piece of reflective tape the size of the markers was placed on the ball so that ball velocity could be calculated. Similar to FV, ball velocity was calculated by dividing the distance the marker on the ball traveled over 4 frames after BR by 0.01668 (4/frame rate).
To evaluate the temporal values of the subject’s mechanics, the timing of maximum angular velocity of pelvic rotation (MP), trunk rotation (MT), and shoulder rotation (MS) were determined using the Vicon Nexus motion analysis system. This study used MP as a variable instead of onset trunk rotation as seen in the other studies, so that the timing of all MS, MT, and. Each number was generalized as the occurrence (%) in the pitching cycle between beginning at SFC (0%) to BR (100%) (Aguinaldo & Chambers, 2009).

**Statistical Analysis**

One-paired and two-tailed T-test was performed on Excel spreadsheet to determine if significant differences (P < 0.5) in MST, BV, MP, MT, and MS existed between the pre and post coaching trials.
Results

There was no significant difference (P < 0.05) in the average MST between before and after the 15 minute coaching session (P = 0.31) (Figure 2). Mean shoulder torque during the pre-coaching session shoulder torque was 41.1 Newton Meters (N·m) (Table 2), and mean shoulder torque during the post-coaching session was approximately 44.7 (N·m).

Figure 2: The comparison of maximum shoulder torque between pre and post coaching sessions
Table 3

Individual test results

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Pre</th>
<th>Ave MP (%)</th>
<th>Ave MT (%)</th>
<th>Ave MS (%)</th>
<th>Ave FV (m/s)</th>
<th>Ave BV (m/s)</th>
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<tbody>
<tr>
<td>Subject #1</td>
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<td>Subject #2</td>
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<td>Subject #3</td>
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<td>Subject #9</td>
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</tbody>
</table>

Note. MP = Maximum Pelvic Rotation
Note. * = Missing Data
MT = Maximum Trunk Rotation
MS = Maximum Shoulder Rotation
FV = Finger Velocity
BV = Ball Velocity
There was a significant difference in average FV between pre and post coaching sessions (P = 0.004) (Figure 3). Mean FV of the pre coaching session was 16.8 (m/s), and mean FV of the post coaching session was 18.0 (m/s). There was no significant difference in BV between pre and post coaching session (P = 0.187). The average mean BV was slightly faster in post coaching session 20.8 (m/s) than pre coaching session 20.0 (m/s) (Figure 3).

Note. *p < .05.

Figure 3: The comparison of average finger velocity and ball velocity between pre and post coaching sessions
No significant differences (P < 0.5) were found in the timing of MP, MT, and MS between pre-coaching and post-coaching sessions (Figure 4). Timing differences between pre and post-coaching sessions for MP, MT, and MS were -0.3 %, 0.2 %, and 2.3 % (Table 2) respectively. Although statistical analysis did not demonstrate differences in the timing, there may be practical timing differences in the subjects’ pitching motion.

Although, there was no significant difference in the average timing between MP and MT, torso rotation occurred 5% later in the pitching cycle on the post-test. This result indicated that the coaching session may have facilitated delayed trunk rotation during the pitching motion. While five of nice subjects exhibited the correct order of MP, MT, and MS, four subjects demonstrated incorrect sequencing of MP, MT, and MS in the pre coaching session. However, three out of nine subjects exhibited improper sequencing in the post coaching session (Table 2).
Figure 4: The comparison of average timings of max pelvis rotation, max torso rotation, and max shoulder internal rotation between pre and post coaching sessions.
Discussion

The purpose of the present study was to determine if a 15 minute coaching session that corrects common errors during baseball pitching made a significant difference in MST which is believed to be related upper limb injuries from the repetitive pitching motion. The results revealed that subjects’ shoulder torque was not significantly changed (P < 0.05) after the coaching session.

The test results showed two subjects decreased their MST after the coaching session, and three subjects increased their MST. Aguinaldo et al. (2007) stated that there is a correlation between later trunk rotation and decreased shoulder torque. Although there were no significant differences in timing of MP, MT, and MS, increased delays were observed after the coaching session (Figure 3). Although not statistically significant, increased delays between MP, MT, and MS can be considered improved pitching mechanics.

A possible reason for causing an increase of MST is the improvement of subjects’ performance (ball velocity). Some studies showed that raw MST increases as the subjects become more skilled (Aguinaldo et al., 2007; Fleisig et al., 1999, Guo et al., 2009). Since this study analyzed inexperienced subjects, performance improvements may have been due to increased velocities of MP, MT, and MS. Since MST is highly related to MS velocity it would be natural for MST to increase as ball velocity increases. The better skilled subjects may reduce shoulder torque by improving the mechanics while they may be closer to maximum shoulder velocity due to training and maturity. In addition, the
three subjects who increased their MST originally had lower (No. 2, 4, and 5 in the rank) MST which can be reflected by their original poorer skill level.

According to Aguinaldo et al. (2007), mean shoulder torque for youth pitchers was 33 ± 3 (N•m), and 66 ± 6 (N•m) for high school pitchers. Female subjects in this study increased MST from 15.1 (N•m) to 19.2 (N•m), and male subjects increased their MST from 58.3 (N•m) to 61.7 (N•m). According to Aguinaldo et al. (2007), MST was indicative of skill level and body mass. This may be one reason that the MST values are similar to Aguinaldo.

Timing of MS in the pitching cycle can be compared with the data from Guo et al. (2009). According to Guo, average MS of the professional pitchers occurred in the late 60% of the pitching cycle, while average MS for the amateur group occurred 70% into the pitching cycle. Although Aguinaldo and Chambers (2009) did not present timing of MS, timing of maximum elbow flexion appeared very similar to Guo’s data (mean 51%). However, the mean MS for subjects in this study in the pre-test occurred at 77.8% of the pitching cycle, while mean MS in the post-test occurred at 84.6% of the pitching cycle. One possible reason could be that since this study’s subjects are novice throwers, the subjects’ shoulder did not externally rotate as far as experienced throwers due to the lack of the shoulder internal rotators’ flexibility (Brown, Niehues, Harrah, Yovorsky, & Hirshman, 1988). That may be why their MS became such close to the BR.

One of the purposes of this study was that the coaching session was supposed to encourage a delay of the subjects’ trunk rotation which should cause to delay timing of MS as well. Thus, it is important to see the whole timing balance of the kinetic chain, and
it is dangerous to simply compare the previous study’s results and the skilled pitchers’ results.

Interestingly, FV velocity was significantly greater after the coaching session even though there were no significant improvements in timing of MP, MT, and MS. Although timing differences were not significant, small improvements in each temporal parameter could contribute to a significant change in FV. This may highlight the importance of each link in the kinetic chain and small improvements in multiple components may improve performance.

The reason why there were no significant differences in timings of MP, MT, and MS is that the length of coaching session was not long enough for subjects’ movements could be done without conscious control. There are some inconsistent numbers within the same subjects’ post coaching session data. These inconsistencies could be explained by the lack of subject’s experience in throwing. In order to gain a firm control on proper pitching mechanics, the subjects needed multiple training sessions or a long term training program.

According to Aguinaldo and Chambers (2009), the group whose onset trunk rotation was earlier than SFC had a significantly higher elbow valgus torque. The current study used the variable “maximum velocity of trunk rotation”, and this should occur later than Aguinaldo and Chambers’ definition of “onset trunk rotation”. Furthermore, it is assumed that subjects who had an earlier onset trunk rotation would have an earlier MT timing. They concluded in the study that there was correlation between later trunk rotation and reduced elbow valgus torque. Werner et al. (2002) insisted elbow valgus
torque and shoulder external torque were significantly correlated. Thus, this study’s result: Subjects who do not have much difference in timing of trunk rotation still significantly increase their MST, this is contrary to Aguinaldo and Chambers’ finding.
Conclusion

A 15 minute coaching session focused on correcting common pitching errors improved the timing of MP, MT, and MS rotations. Although the changes in the timing of rotations were not statistically significant, MT was delayed 5% later in the pitching cycle. In addition, FV was the only parameter that was significantly greater after the coaching session. The small percentage changes in the timing between segment rotations (MP, MT, and MS) and the fact that MT occurred 5% later in the pitching cycle could have cumulatively caused the increase in FV.

MST also increased after the coaching session although the change was not significant. This may have occurred because the subjects in this study were novice pitchers. Lower level performers will experience an increase in joint velocities and torques as their skill level improves.

Further research is need on the impact of pitching errors on the timing of segment rotations and shoulder torque. Researchers need to determine the effect of the common errors on pitching mechanics and shoulder and elbow torque. Various methods of correcting these errors also need to be researched further.

Coaches should encourage delayed pelvic rotation to improve the overall pitching performance.
References


Appendix A

Par- Q and You and Subject Information

Subject Name-___________________________________________ Subject code-

________________

Height- ________ Weight- ________ Age- ________ Gender- ________

Please place an “x” in the appropriate box.

Health Questions Yes No

Has your doctor ever said that you have a heart condition and that you should only do
physical activity recommended by a doctor?

Do you feel pain in your chest when you do physical activity?

In the past month, have you had chest pain when you were not doing physical activity?

Do you lose your balance because of dizziness or do you ever lose consciousness?

Has your doctor ever said that you have bone or joint problem and that you should only
do physical activity recommended by a doctor?

Is your doctor currently prescribing drugs (for example water pills) for your blood
pressure or heart condition and said that you should only do physical activity
recommended by a doctor?

Do you know of any other reason why you should not do physical activity?
Has your doctor ever said that you have diabetes and that you should only do physical activity recommended by a doctor?

Are you pregnant and has your doctor said that you should only do physical activity recommended by a doctor?

***If you answered “YES” to any of these questions please consult your doctor before you begin any physical activity.***

Adapted from http://uwfitness.uwaterloo.ca/PDF/par-q.pdf
Appendix B

Adult Informed Consent Form
California State University, Northridge

Title of the Study: The Influence of Pitching Mechanics on Joint Torques and Sequential Timing
Principal Investigator: Dr. Shane Stecyk (phone: 818-677-4738)

DESCRIPTION OF THE RESEARCH

You are invited to participate in this investigation which will look at how your body moves while throwing a baseball. The results of this study may be helpful to athletic trainers, physicians, physical therapists, strength and conditioning coaches, and baseball coaches to prevent injuries and improve performance. This study will include healthy males and females. The study will be under the supervision of Dr. Shane Stecyk, Director of the Athletic Training Education Program at CSUN.

WHAT WILL MY PARTICIPATION INVOLVE?

If you decide to participate in this research you will receive an orientation session which will include:

- Informed consent, Subject's Bill of Rights, and PAR-Q.
- Complete measurements and testing (see Dr. Stecyk for complete list).
- Complete your own warm-up so that you are ready to throw at least 90% effort.
- Throw practice pitches until you are comfortable throwing in the laboratory or until you feel fatigued.
- Practice the Single Leg Squat, Step Down, Vertical Jump, Single Leg/Single Hop, and Edgren Side Step tests.

The orientation session will take approximately 60 minutes.

Testing will take approximately 60 minutes and will include:

- You will complete your own warm-up so that you are prepared to throw at least 90% effort.
- You will wear spandex shorts. Males will be shirtless and females will wear a tank top/sports bra so that the markers are easier to attach.
- Markers will be attached using double sided tape.
- You will continue your warm-up by pitching to the target (37 feet away) in the laboratory.
- Once you are warmed up we will record five pitches.
- Complete the Single Leg Squat, Step Down, Vertical Jump, Single Leg/Single Hop, and Edgren Side Step tests.

You will be randomly assigned to 1 of 4 treatment groups:

- Group 1- Control Group
- Group 2- Individual throwing/coaching sessions with the researcher providing feedback (15-30 minute training sessions).
- Group 3- Slide board training (lateral) (15-30 minute training sessions).
- Group 4- Slide board training program (lateral and rotational) (15-30 minute training sessions).

You will complete a 12 week training program, which will be completed at California State University, Northridge. The training program consists of 2 training sessions/week for the first 2 weeks, and 3 training sessions/week for the remaining 10 weeks.

- After you finish the 12 week training program, measurements and testing from the orientation session will be taken again. You will then go through letters a-f above.
- You will be retested 4 weeks later for the retention trial. Testing will be completed as outlined above in points a-f.
ARE THERE ANY RISKS TO ME?

Potential risks are minimal since your health status will be screened using a participation survey, you will be provided with an appropriate warm-up, and you will throw only 5-10 pitches for each data collection session. However, normal risks associated with exercise (such as muscle soreness). Although highly unlikely, subjects could suffer a significant muscle strain during one of the pitches.

ARE THERE ANY BENEFITS TO ME?

You will not receive momentary compensation for participation in this study. However, you will receive individual and group coaching. You may experience improvements in your fitness level and throwing motion.

HOW WILL MY CONFIDENTIALITY BE PROTECTED?

Confidentiality will be maintained by coding participant names so that individual identities will remain unknown. During the course of the study participants will be video taped and photographed. All tapes/data will be kept on file in a locked cabinet.

Your initials here signify your consent to be video taped.

Your initials here signify your consent to be photographed.

WHOM SHOULD I CONTACT IF I HAVE QUESTIONS?

If you have questions about the research contact Research and Sponsored Projects, 18111 Nordhoff St, CSUN, Northridge, CA, 91330-8232, or phone 818-677-2901. If you have specific concerns contact Dr. Shane Stecyk, at 18111 Nordhoff St, Northridge, CA, 91330-8287 or by phone at 818-677-6738.

Your participation is completely voluntary. If you decide not to participate or to withdraw from the study it will have no effect on any services or treatment you are currently receiving. The researchers may also cancel the study at any time.

I have read the above and understand the conditions outlined for participation in the described study. I give informed consent to participate.

Name of Participant (please print):

________________________________________

Signature _____________________________ Date _____________________________

Witness/PI Signature- _____________________________ Date- _____________________________

If you have signed this form, please return one copy in an envelope to:
Dr. Stecyk
Department of Kinesiology
California State University, Northridge
18111 Nordhoff St
Northridge, CA 91330-8287

CSU, Northridge
Human Subjects Committee
Approved: 8/13/01
Void After: 8/13/11
Appendix C

Plug-in-Gait Marker Placement

The following describes in detail where the Plug-in-Gait markers should be placed on the subject. Where left side markers only are listed, the positioning is identical for the right side.