THE RELATIONSHIP BETWEEN CORE STABILITY AND THROWING VELOCITY IN COLLEGIATE BASEBALL AND SOFTBALL PLAYERS

THESIS

A THESIS

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BY

CHARLES MICHAEL GREEN

Research Advisor, Dr. Bruce Barnhart

California, Pennsylvania

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CALIFORNIA UNIVERSITY OF PENNSYLVANIA
California, Pennsylvania

THESIS APPROVAL

Athletic Training

We hereby approve the Thesis of

Charles Michael Green
Candidate for the degree of Master of Science

Date          Faculty

4/28/05        Bruce D. Barnhart
               Dr. Bruce Barnhart - Research Advisor

4/28/05        Dr. Rebecca Hess - Committee Member

4/29/05        Prof. Barry McGlumphy - Committee Member
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INTRODUCTION

In recent years, core stabilization has become the buzzword in health and fitness. Numerous abdominal training devices and videos have been marketed all across America to capitalize on this trend. However, to athletic trainers and strength and conditioning professionals, this is not a trend at all. The importance of core stability has been emphasized for decades, albeit the terminology has changed. We also understand in this day and age that the term “core” means much more to our discussion of the human body than just the abdominals. The core refers to the entire lumbo-pelvic-hip complex and its related structures. The role of the core is of utmost importance as it relates to optimal functioning of the kinetic chain during many athletic activities.

The core is the centerpiece of the body. It is responsible for providing dynamic postural control during functional movements. It also helps maintain normal arthrokinematics, or coordinated movement, of the joints within the kinetic chain. The core serves as the center of movement for the body by stabilizing one’s trunk and spine before movement is initiated and by maintaining the center of gravity over their base of support during movement.
Anatomically, the core is comprised of the trunk and upper and lower extremity girdles, the focal point of which is the pelvis. Important abdominal muscles include the rectus abdominis, transversus abdominis, internal obliques, and external obliques.\textsuperscript{3,4} The transversus abdominis is of particular significance as it has been shown to be the first muscle to fire when body movement is initiated.\textsuperscript{4} Therefore, any good training program for pitchers should include exercises designed specifically to increase neuromuscular activity of the transversus abdominis.

The involved back musculature includes the erector spinae, quadratus lumborum, multifidus, semispinalis thoracis, and semispinalis cervicis.\textsuperscript{3} At the shoulder complex, the rotator cuff, trapezius, rhomboids, latissimus dorsi and serratus anterior are of primary consequence. These muscles serve to ensure optimal scapulothoracic rhythm between the scapula and humerus, and also carry the responsibility of decelerating the limb and dissipating force.\textsuperscript{5-7} The rotator cuff is often injured in pitchers due to the fact that its anatomical location places it at a mechanical disadvantage to generate or decelerate large amounts of force.\textsuperscript{5}

While many methods and devices have been designed to train the core, with varying degrees of success, the most
effective methods for training the core are the ones that mimic a crunch.\textsuperscript{8-12} Crunches were developed years ago as the mechanics of sit-ups were altered over time to protect the spine and better isolate the abdominals. They are still considered the standard exercise by which to train the abdominals. Pelvic tilts have also been shown to elicit high EMG activity of the core musculature.\textsuperscript{13} However, crunches and tilts are nonfunctional in that they do not imitate athletic activity. Strength and conditioning professionals agree that the best way to enhance athletic performance is to design programs that re-create the demands of a given sport.

Several more sport-specific core stability assessment tests have been developed, although the validity and reliability of these tests is still being determined. These include the Overhead Squat Test, Single-Leg Balance Excursion Test, Prone Iso-Abs Test, and the Overhead Medicine Ball Throw.\textsuperscript{2} These tests have been designed to measure functional flexibility, strength, and power in all three planes of motion, just as the overhead throw takes place in all three planes.

Baseball especially is a sport in which synchronicity and efficiency of the kinetic chain is critical for peak performance, and requires a unique and precise blend of
stability, strength, power, and speed. With no activity on the field is this more evident than with pitching. The timing and sequence of muscle activity during an overhand throw is absolutely crucial to the development of pitch velocity. The upper extremity will be moving at anywhere from \(6500-7200^0/s\) when it reaches its maximum angular velocity in a professional level pitcher.\(^{14}\) Because of the extremely large numbers involved, developing power from the core early on, as well as decelerating and dissipating the force generated, must be accomplished precisely and efficiently to minimize the risk of injury to the shoulder girdle. Such injury may invariably occur when the arm is moving at such a high rate of speed.

The pitch, or overhand throw is a highly synchronized pattern of movement in athletics. It is typically broken down into five stages: wind-up, early cocking, late cocking, acceleration, and follow-through.\(^{15}\) Initiation of the movement comes from the core, the transversus abdominis in particular which is recruited during forced exhalation and serves to “set” the trunk. The early stages of the overhand throw serve primarily to place the body in position to maximize the use of as many kinetic chain segments as possible. This body positioning is largely due to the Serape Effect, which is a coordinated series of
muscle activity within the core.\textsuperscript{16} When these motions occur in the proper sequence with appropriate timing, energy is transferred in a proximal-to-distal manner from the trunk and lower extremity through the spine to the shoulder complex and upper extremity.\textsuperscript{7,17,18} The scapula plays a key role in this process due to its articulation with the thoracic cage and the humerus. The scapula is the bony link between the core and upper extremity and is responsible for creating a stable base around which the arm rotates. It also must be mobile to move in synchronicity with the humerus to ensure optimal arthrokinematics. In addition, the stabilizing musculature of the scapula must also act to dissipate the deceleration forces created by the rotator cuff as it attempts to slow the limb down. This is essential for reducing the risk of injury while also allowing maximum pitch velocity to be generated.

The purpose of this study was to determine the relationship between core stability and throwing velocity in overhand-throwing collegiate athletes. The following questions were examined in the area of core stability and its relationship to throwing velocity: (1) Is there a relationship between functional flexibility (as measured by the overhead squat and single leg balance excursion tests) and throwing velocity? (2) Is there a relationship between
functional strength (as measured by the prone iso-abs test) and throwing velocity? and (3) Is there a relationship between functional power (as measured by the overhead medicine ball throw) and throwing velocity?
METHODS

The purpose of this section is to describe in depth the methodology of the proposed study, and is comprised of the following sections: Research Design, Subjects, Preliminary Research, Instrumentation, Procedures, Hypotheses, and Data Analysis.

Research Design

A descriptive correlational design was used for this study. The independent variables were the various scores of the functional tests selected to assess the individual components of core stability - flexibility, strength, balance, and power. These National Academy of Sports Medicine (NASM) functional tests include the Overhead Squat Assessment, Single-Leg Balance Excursion Test, Prone Iso-Abs Test, and Overhead Medicine Ball Throw. The dependent variable was throwing velocity as measured by a JUGSTM radar gun. Each individual subject was tested in one session and testing took place on various days of the week, depending upon the personal schedule of the subject. Testing of all subjects took approximately two weeks. Other physical demands of the subjects were also considered. For example,
subjects were tested on days when they did not participate in team practice or other physical activities, or they were tested earlier in the day before such activity took place.

The external validity may be compromised in that the subjects that were chosen were limited to student-athletes from California University of Pennsylvania only, therefore it was assumed that this sample is representative of the entire population of NCAA Division II baseball and softball players only.

Subjects

Subjects included volunteer male college baseball and female college softball players from California University of Pennsylvania. All subjects were actively participating in regular in-season conditioning at the time testing was conducted. All volunteers wishing to participate in the study were allowed to do so due to the small population of athletes (N~40). Each subject’s performance of the selected NASM functional tests was assessed and scored according to the guidelines set forth by the NASM. Subjects with previous or current injuries or conditions that prevent them from completing functional and/or throwing tests in a
natural and comfortable manner were not included in the study.

All participants were required to complete and sign an informed consent form before participation (Appendix C1). Medical records were up-to-date at the time testing began, therefore obtaining physician approval before participation was not necessary. Demographic information such as age, reported height and weight, gender, previous injury history of the upper extremity, lower extremity, or trunk, total years of playing experience, and playing position were collected through a subject information questionnaire (Appendix C2).

Preliminary Research

Preliminary research involved an assessment of the various components of the proposed study. Trials of each of the NASM functional tests were completed to determine the amount of time required to administer each test and to determine the viability of each test to the study. Trials with the radar gun were made to allow the researcher to become comfortable and proficient with the equipment to ensure accurate measurements. Two volunteer subjects were
chosen to participate in the preliminary research and were not included in the actual research.

Instrumentation

A JUGS™ radar gun, subject information questionnaire, and selected assessments from the NASM Optimum Performance Training for the Performance Enhancement Specialist course manual were used for this study. The selected functional tests were specifically recommended for baseball by the NASM. These tests were created by the NASM, based on sound scientific principles, to determine an individual’s functional physical ability (Appendix C3). The outcome of the study will contribute to the validity and reliability of these assessments.

Overhead Squat Assessment

The Overhead Squat Assessment is a measure of functional flexibility and dynamic postural deviations. With this test the presence of deviations are observed and noted according to the NASM checklist. Each noted deviation is counted as a point. Therefore as the subject’s score increases, their performance is considered to decrease. The
Overhead Squat Assessment was scored on a scale of zero to eleven total points.

**Single-Leg Balance Excursion Test**

The Single-Leg Balance Excursion Test is a measure of functional flexibility, strength, and balance. Once again, postural deviations were noted during performance of the exercise and were each counted as a point. As the score increased, performance decreased. The Single-Leg Balance Excursion Test was scored on a scale of zero to nine total points.

**Prone Iso-Abs Test**

The Prone Iso-Abs Test is a measure of functional core strength. This is a test in which the subject’s posture was once again observed for deviations as outlined by the NASM. An inverse relationship between the test score and performance once again existed. The Prone-Iso Abs Test was scored on a scale of zero to nine total points.

**Overhead Medicine Ball Throw**

The Overhead Medicine Ball Throw is an assessment of core power and is measured by distance the ball is thrown. Distance for the purposes of this study was measured with a
tape measure in inches. As the distance increased, the subject’s performance was also considered to increase. The subject was asked to complete three throws and the best score was used.

**Throwing Velocity**

Throwing velocity was determined by use of a JUGS™ radar gun. The researcher had become proficient with the radar gun as part of the preliminary research. The radar gun was assumed to have been calibrated prior to the study and is the most widely accepted instrument used to measure throwing velocity. The throwing velocity measurement protocol is included in the appendices (Appendix C4).

When possible, scores were measured and recorded solely by the researcher. However, the researcher may have needed to request assistance collecting data from the subjects if the sample of volunteers became too large to test within a reasonable time period. In that case, the assistant would have had professional credentials (ATC) and background (as a student enrolled in the NASM OPT™ course) similar to those of the primary researcher. Additionally, the researcher and assistant would have collaborated and agreed upon a standardized method of judging and scoring
postural deviations. This would have been done to ensure reliability of the scores and minimize the risk of external factors jeopardizing the validity of the study. In the case of this study, all data was collected solely by the researcher and therefore the above mentioned protocol was deemed unnecessary.

Procedures

Before beginning the study, the researcher requested and received IRB approval (Appendix C5). This is to ensure fair and humane treatment of all research subjects. Prior to the start of subject testing, permission from the baseball and softball coaches from California University of Pennsylvania was obtained verbally in a brief meeting between the coaches and researcher. This was to verify that approval had been granted to use baseball and softball athletes from California University of Pennsylvania and that all participating subjects had a pre-participation physical or physician clearance. The researcher then asked for volunteers from both the baseball and softball teams. All athletes that volunteered to participate were included in the sample. Each subject was assigned a number to preserve their anonymity. The athletes were reminded that
they were under no obligation to participate in the study and that they would be able to withdraw from participation at any time. Before testing began, all volunteering subjects were asked to complete a subject information questionnaire. Obtaining physician clearance was not necessary prior to participation. The researcher addressed all questions and concerns of the subjects before, during, and after completion of the study.

Scores from each of the functional tests were recorded on a master score sheet (Appendix C6). Complete descriptions of each test are included in the appendices. Each subject met with the researcher in a one-on-one situation. During this time each of the tests were administered. Testing for each subject lasted approximately 30 minutes. Testing times varied with the throwing velocity assessment due to the individual warm-up times for each subject. The researcher scheduled as many subjects for testing in a day as he deemed reasonable. Testing order was controlled by the researcher by administering the tests in the same order for each subject.

Each functional test was administered according to the protocols set forth by the NASM (Appendix C3). Each subject was shown the photo included in the NASM manual which accompanies the given test, but they were not shown the
checklist of postural deviations so they are encouraged to complete the test as naturally as possible without the bias of knowing the various deviations.

A warm-up period was provided for each subject prior to completing the series of overhand throws. The warm-up consisted of light throwing from a shorter distance than the one to be tested, and the subject gradually increased the throwing distance and intensity as they deemed appropriate. It was left to the subjects' discretion to decide when they were ready to begin testing. Test trials were completed from such a distance that maximum force could be generated, but not from any distance specific to baseball or softball. This controlled for gender bias within the study. Each subject was then allowed three practice throws toward the target before testing began. Once testing began, the best of the three measured throws was used as the final score.

The testing was completed three to four times weekly, spanning two weeks. Times were scheduled based on the availability of each of the subjects on the given day. It was recommended to subjects to wear athletic clothing on the day they were to be tested. Throwing velocity measurements and functional test scores were taken using
the facilities and equipment of California University of Pennsylvania.

Hypotheses

The researcher, based on the review of literature and intuitive judgment, made the following hypotheses in the categories of NASM functional assessment scores and throwing velocity:

1) There will be a negative correlation between functional flexibility scores (as measured by the Overhead Squat Test and the Single-Leg Balance Excursion Test) and throwing velocity.

2) There will be a negative correlation between functional strength scores (as measured by the Prone Iso-Abs Test) and throwing velocity.

3) There will be a positive correlation between functional power scores (as measured by the Overhead Medicine Ball Throw) and throwing velocity.
Data Analysis

The data collected in this study was analyzed using SPSS version 12.0. A Pearson Product Moment Correlation was used to determine the relationships between functional flexibility, strength, and power and throwing velocity as described in hypotheses one through three. The alpha level for these statistical tests was set a priori at ≤ .05.
RESULTS

The purpose of this study was to determine if core stability was related to throwing velocity in collegiate baseball and softball players. Subjects were tested once to determine their individual level of core stability and once more to obtain throwing velocity measurements. Testing was conducted over a two-week time period. Core stability assessments were conducted utilizing the functional tests and associated checklists developed by the National Academy of Sports Medicine. These tests include the Overhead Squat, Single-Leg Balance Excursion, Prone Iso-Abs and Overhead Medicine Ball Throw. Throwing velocity measurements were taken using a JUGS™ radar gun.

Data collected from the subject information questionnaire included demographics such as age, gender, reported height, reported weight, recent history of injury, years of playing experience at all levels, and position played. The results are divided into three sections: demographic data, hypothesis testing, and additional findings.
Demographic Data

A total of 25 subjects (N = 25) completed this study. The subjects were mixed gender volunteers (7 males, 18 females).

All of the subjects were physically active individuals, participating in NCAA Division II athletics at California University of Pennsylvania. Core stability tests were administered by the examiner and were scored according to the postural deviations checklist provided by the NASM. All tests were administered solely by the researcher to ensure reliability of the results. Demographic data can be viewed in Table 1.

Table 1. Demographic Data

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<thead>
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</table>
Hypothesis Testing

The following hypotheses were tested for this study. All tests of statistical significance used an alpha level of .05. A summary of the results can be found in Table 2.

Hypothesis 1: There will be a negative correlation between functional flexibility scores (as measured by the Overhead Squat Test and the Single-Leg Balance Excursion Test) and throwing velocity.

Conclusion: A Pearson Product Moment Correlation was used to determine if lower functional flexibility scores resulted in higher throwing velocity measurements. No significant results were found. The Overhead Squat test yielded an $r = -.027$ (df = 23; $P = .899$). The Single-Leg Balance Excursion test yielded an $r = .221$ (df = 23; $P = .289$). Functional flexibility scores were not related to throwing velocity scores.

Hypothesis 2: There will be a negative correlation between functional strength scores (as measured by the Prone Iso-Abs Test) and throwing velocity.

Conclusion: A Pearson Product Moment Correlation was used to determine if lower functional strength scores
resulted in higher throwing velocity scores. The Prone Iso-Abs test yielded an $r = -0.109$ (df = 23; $P = 0.604$). Functional strength scores were not related to throwing velocity scores.

Hypothesis 3: There will be a positive correlation between functional power scores (as measured by the Overhead Medicine Ball Throw) and throwing velocity.

Conclusion: A Pearson Product Moment Correlation was used to determine if higher functional power scores resulted in higher throwing velocity scores. A strong positive correlation was found. The Overhead Medicine Ball Throw yielded an $r = 0.920$ (df = 23; $P < 0.001$). Functional power scores had a strong direct relationship to throwing velocity. Subjects who were able to throw the medicine ball a greater distance also produced higher throwing velocity numbers.
Table 2. Correlational Statistics for Core Stability Test Scores and Throwing Velocity Measurements

<table>
<thead>
<tr>
<th></th>
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<th>Prone Abs</th>
<th>MedBall</th>
<th>Throw</th>
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* Correlation is significant at the .05 level (2-tailed).

** OHS = Overhead Squat Assessment
SLBE = Single-Leg Balance Excursion Assessment
Prone Abs = Prone Iso-Abs Assessment
MedBall = Overhead Medicine Ball Throw
Throw = Throwing Velocity

Additional Findings

After testing the hypotheses, further testing was conducted to determine if there were any correlations between the demographic data including age, gender, reported height, reported weight, years of playing experience, and position and throwing velocity. There were no significant correlations found between age or experience relative to throwing velocity. That is to say older players
showed no significant difference in throwing velocity numbers than younger players and players with more experience did not throw significantly faster than players with less experience. Additionally, pitchers did not exhibit higher throwing velocity numbers than position players. Furthermore, no significant difference was found in throwing velocity numbers within the sample of position players. Outfielders, for example, did not throw significantly faster than infielders or catchers.

There were, however, significant findings discovered between gender, reported height, reported weight, and throwing velocity. Average throwing velocity measurements in males were higher than in females, as summarized in Table 3. An Independent t-Test yielded a t = 7.25 (df = 23; P = .013). This indicates that males are able generate more force than females. A Pearson Product Moment Correlation between height and throwing velocity yielded an r = .848 (df = 23; P < .001). A Pearson Product Moment Correlation between weight and throwing velocity yielded an r = .721 (df = 23; P < .001).

<table>
<thead>
<tr>
<th>Gender</th>
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<th>Standard Error Mean</th>
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<td></td>
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</table>

Table 3. Throwing Velocity by Gender
DISCUSSION

The following section is divided into three parts: discussion of results, conclusions, and recommendations.

Discussion of Results

The purpose of this study was to determine if core stability was related to throwing velocity in collegiate baseball and softball players.

It was initially hypothesized that lower scores on the Overhead Squat, Single-Leg Balance Excursion, and Prone Iso-Abs tests would correlate to higher throwing velocity numbers. Statistical analysis demonstrated that there was no significant relationship between the scores for each of these three tests and throwing velocity.

There may be several possible reasons that the results were not as expected. The most probable of these is that the sample size was small and restricted to a very specific area. A larger sample size spanning a wider range of competition levels would have been more desirable. Although all but one (due to injury) of the softball players participated in the study, several of the baseball players were not permitted to be included at the request of the
coach. Being that the team was in season, the baseball coach had reservations about players being injured while performing the throwing velocity test. Therefore, the sample size of male baseball players was less than optimal.

There is also the possibility that some of the subjects did not give their best effort when performing the tests, despite verbal encouragement from the examiner. Due to the fact that testing was performed in-season, some of the subjects might have felt compelled to “save their arms” for competition.

Yet there is even a third possibility wherein the subjects simply have not learned to efficiently generate power from the core. In other words, many of the subjects may simply have had less-than-optimal throwing mechanics based on the review of literature.\textsuperscript{1,2,4-7,14-22} When the muscles of the core are functioning properly, it allows for the maintenance of normal length-tension relationships among functional agonists and antagonists within the lumbo-pelvic-hip complex. This in turn allows normal force-couple relationships to be maintained which results in optimal arthrokinematics in the various joints of movement within the kinetic chain.\textsuperscript{1} When the muscles of the core are not functioning properly, there is an inefficient transfer of force through the kinetic chain to the upper extremity.
Much of the force initially produced by the core and lower extremity is lost before it reaches the shoulder and arm, and throwing velocity is decreased as a result. It may have been assumed that by the time an overhand-throwing athlete has reached the NCAA Division II level of competition, they have learned how to efficiently transfer force to the upper extremity to perform at a high level. The statistics suggest, however, that this may not be a safe assumption in all cases. The core may be less of a factor in power development and terminal throwing velocity than previously thought.

There are several contradicting theories regarding the exact role of the core based on the review of literature. A text written by Hamilton and Luttgens\textsuperscript{20} suggests that the activation of abdominal musculature plays a large role in the early stages of power development, the main purpose being to put the body in a position to activate the most number of kinetic chain segments possible to develop the most force possible.\textsuperscript{15} This is accomplished largely through pelvic rotation in the opposite direction from the intended throw, followed closely by forceful rotation in the same direction as the throw. Wight et al\textsuperscript{19}, in their study of pelvic rotation styles, suggest that the exact timing of pelvic rotation during the overhand throw is not critical
to the development of power. Pitch velocity had been found to not be significantly affected solely by differences in pelvic rotation patterns. Still other sources suggest that a strong push-off and forward step or efficient internal rotation of the shoulder is the key to power development. In actuality, the real answer is most likely a combination of all of these. The exact sequence and importance of each component, however, needs to be the subject of further research.

The Overhead Medicine Ball Throw, conversely, was shown to be directly related to throwing performance. It was initially hypothesized that there would be a positive correlation between the distance the medicine ball was thrown and throwing velocity. The results suggest that the mechanics of an overhand throw also apply to other types of throws. Research has indicated that the transversus abdominis is the first muscle to fire when movement within the kinetic chain is initiated. Therefore, all functional movement originates with the core. Regardless of the exact mechanics by which force is transferred through the kinetic chain to the upper extremity and for what purpose, the fact remains that it must be transferred efficiently to maximize performance of the given task. Increased performance of the Overhead Medicine Ball Throw would seem to indicate that
those subjects have learned how to generate and transfer force more efficiently than subjects who did not perform as well.

Conversely, the highest medicine ball distances were recorded by male subjects, as were the highest throwing velocity scores. It was discovered that the best performances of these two throwing tests came from the subjects that were the tallest and heaviest, which were also the male subjects. Based on the review of literature regarding the mechanics of force development it would seem that a larger body size would aid in the performance of throwing assessments for a couple of reasons.\textsuperscript{1,2,4-7,14-22} Larger muscles typically found in males are able to create more tension and more force production, due to the potential to recruit more muscle fibers. Also, longer muscles found in taller subjects result in longer lever arms which produces greater force production. These possibilities, it should be noted, have yet to be substantiated through research and further testing in this area is recommended.
Conclusions

Based on the results of the study, the exact role and importance of the core has yet to be thoroughly determined. Measures of functional flexibility and strength showed no relationship to throwing velocity. However, measures of functional power as a component of core stability show a strong positive relationship to throwing velocity. This information may be meaningful to athletic trainers and strength and conditioning professionals who work with overhand-throwing athletes. The results of this study would suggest that the most effective methods for strengthening the core would include dynamic power exercises that are similar in nature to dynamic power development associated with overhand throwing.

Recommendations

While this study examined the relationship between core stability and throwing velocity, further research is needed to further determine if any correlation exists between the variables. The following recommendations are suggested for future research in this area.
1) A greater number of subjects spanning a wider range of competitive levels may yield different results.

2) Testing might best be conducted during the off-season, so the concern for injuries and/or overtraining is minimal.

3) More research is necessary to support the validity of the core assessment tests developed by the NASM.
REFERENCES


APPENDIX A

Review of the Literature
Introduction

Core strengthening and stabilization has become widely recognized as a critical component in the optimal functioning of the kinetic chain in many athletic activities. Baseball, in particular, is a sport in which optimal functioning of the kinetic chain is essential for peak performance. The following paper is a selected review of the literature on core stability and its relationship to the overhand throwing motion. This review will include: (1) What is the Core?, (2) Developing Pitch Velocity, (3) The Role of the Core in Overhand Throwing, and (4) Summary.

What is the Core?

In its simplest terms, the core is the center of the human body. It is where our center of gravity is located and where all movement begins. The first and most important role of the core is to provide dynamic postural control during functional movements.\(^1\) Anatomically speaking, the core is defined as the lumbo-pelvic-hip complex.\(^2\) When the muscles of the core are functioning properly, it allows for the maintenance of normal length-tension relationships among functional agonists and antagonists within the lumbo-
pelvic-hip complex. This in turn allows normal force-couple relationships to be maintained which results in optimal arthrokinematics in the various joints of movement within the kinetic chain.² Essentially, a properly functioning core provides for optimal efficiency of movement. Since proper movement begins at the core, let’s take a closer look at the important functional anatomical structures that initiate this series of events.

The abdominal muscles are generally the first muscle group that comes to mind when considering the core. The abdominals consist of four muscles: rectus abdominis, external oblique, internal oblique, and transversus abdominis.³,⁴ These muscles are of extreme importance within the core. A well-toned abdomen superficially protects the deeper abdominal viscera from direct trauma during athletic activities.³ However, with regard to the spine, the abdominals function as a unit to provide stability in all planes of motion. The abdominals also help provide range of motion in the lumbar spine. These motions include flexion, rotation, and lateral bending.³

Quite possibly the most important of the four abdominal muscles is the transversus abdominis. This muscle serves to provide stabilization against rotational forces as well as to increase intra-abdominal pressure.⁴ This is
achieved via the “hoop” it creates with the thoracolumbar fascia, which has been called “nature’s back belt” by Akuthota and Nadler. Research has indicated that the transversus abdominis is the first muscle to fire when movement within the kinetic chain is initiated.

Also of importance are the muscles of the back which directly provide support to the spine. These muscles include the erector spinae, which consists of the iliocostalis, longissimus, and spinalis. This group is primarily responsible for extension of the spine. The quadratus lumborum is a large, thin muscle that directly attaches to the lumbar spine. It has been found to often work isometrically to provide lumbar support. Several deeper muscles of the spine include the multifidus, semispinalis thoracis and semispinalis cervicis. All of these muscles function as a unit to support the spine and maintain the body’s upright posture during functional movement.

From a bony standpoint, the core is centered around the pelvis. The pelvis is formed by the ilium, ischium, and pubis. The pelvis articulates with the lowest end of the spine, the sacrum, and also provides the acetabula which will help form the hip joints. It is here that the upper
body and lower body become connected. In a manner of speaking, the pelvis is the centerpiece of the body.

**Strengthening Methods**

As the importance of core stability has become recognized, the methods with which to train the core have continued to expand. Sit-ups were of one of the first methods employed to train the abdominals. Over the years sit-ups were modified to become crunches in an effort to protect the spine from injury but also to attempt to better isolate the abdominal musculature. In addition, many commercial abdominal strengthening devices have hit the market to capitalize on this trend. Studies have shown that few if any of these devices have proven to be more successful than traditionally performed crunches. In fact, the devices that elicit the highest response from the abdominals as measured by EMG are the devices that mimic the traditional crunch.

Also found to be an important trunk training exercise is the pelvic tilt. When performed correctly, this exercise uses the abdominals to stabilize the low back. This information can be particularly useful to the athletic trainer when designing a core strengthening program because two of the cornerstone exercises can be performed with no
equipment at all. These exercises can be performed independently which allows the athlete to become proactive with regards to their training. However, there has been some criticism of these methods as they are not functional sports activities.  

Assessment of Core Stability

Because sports activity occurs in all three planes of motion — frontal, sagittal, and transverse — the core should be assessed and trained in all three as well. Often, transverse or rotational movements are neglected in core training. The multidirectional reach test and the star-exursion test are currently being proven to be valid and reliable tests of multiplanar excursion. Single-leg squat tests also serve as valid tools of assessment. The prone iso-abs test has also been shown to evaluate neuromuscular efficiency of the core stabilization system. These evaluative tools allow for selection of individualized core training programs emphasizing areas of weakness and sport-specific movements.

The importance of the core cannot be overstated as it relates to functional movement. As mentioned above, the core is where a person’s center of gravity is located. The core is responsible for keeping one’s center of gravity
over their base of support. In other words, the core helps maintain balance during functional activities. Also, the core helps keep the spine and pelvis in a neutral position. When the spine and pelvis are not maintained in a neutral position, muscle imbalances may be caused and normal arthrokinematics of the extremities is disrupted. Dynamic postural control must be maintained in order to maximize efficiency of movement. The core is vital in the initiation of all movement. In overhand throwing, the transversus abdominis initiates a synchronized series of movements within the lumbo-pelvic-hip complex known as the Serape Effect which will be discussed later in the review.

Developing Pitch Velocity

The overhand throw is one of the most intricate and coordinated movements in all of sports. Efficient, sequential timing is essential for pitching at a high level. In this section we will examine the mechanics of the overhand throwing motion from the core to the extremities.

The overhand throw is commonly broken down into five phases: wind-up, early cocking, late cocking, acceleration, and follow-through. However, Hirashima et al. have
identified six phases which include a stride phase and a differentiation between deceleration and follow-through. Regardless, this series of events is set into motion by the lower body and core. First the legs provide a stable base over which the trunk and other segments act. They also contribute significantly to the force developed during this series of movements.

Wind-Up

While many different pitching styles have been identified, it is generally accepted that the purpose of the wind-up is to put the body in a position to activate the most number of kinetic chain segments possible to develop the most force possible. This body positioning involves pelvic rotation in the opposite direction from the intended throw. During this time, the shoulder becomes horizontally abducted and externally rotated to allow maximum rotation of the trunk and pelvis. The front or “lead” leg becomes flexed and internally rotated at the hip and flexed at the knee. In this position the internal rotators of the shoulder, the abdominals, the erector spinae, and the contralateral trapezius and rhomboids become stretched. This allows the body to utilize the
stretch reflex to generate force production.\textsuperscript{15} The wind-up ends with a forward stride using the lead leg.

**Early and Late Cocking**

This is then followed by pelvic and trunk rotation along with lateral flexion toward the target.\textsuperscript{15} Studies have shown that while some pitchers tend to rotate the pelvis earlier or later in the motion than others, the same results are generally achieved. Pitch velocity has been found to not be significantly affected solely by differences in pelvic rotation patterns.\textsuperscript{12} The lead hip externally rotates while the knee extends which initiates uncoiling of the torso.\textsuperscript{16} This force is transferred up through the spine to the shoulder complex via the scapulothoracic joint. The motion occurring at the trunk and lower extremity allows for increased horizontal abduction and external rotation of the shoulder.\textsuperscript{15} When the shoulder reaches optimal horizontal abduction and external rotation it will then begin to come forward, trailing the movement of the trunk and pelvis. This sets the stage for the acceleration phase in which the upper extremity will reach an angular velocity ranging from 6,500–7,200 degrees per second.\textsuperscript{17}
Acceleration

As the elbow begins to extend during acceleration, there is rapid initiation of internal rotation of the shoulder.\textsuperscript{15} It has been suggested that this combination of concentric elbow extension and internal shoulder rotation contributes significantly to pitch velocity.\textsuperscript{18} The shoulder is now coming forward and continues to adduct as it crosses the front of the body in a downward direction. A forward step in the lower extremity is also utilized to continue the body’s forward momentum as well as to maintain balance. A strong push-off and forward step provides additional acceleration of the trunk and significantly contributes to the resultant pitch velocity.\textsuperscript{16} During this time the ball is released and the body can now begin to dissipate the momentum it has just created.\textsuperscript{15}

Follow-Through

Reduction of the force created is largely the responsibility of the posterior musculature of the shoulder girdle. These include the posterior deltoid, latissimus dorsi, teres major, rhomboids, and trapezius (middle trapezius specifically). However the most important muscle group of all for deceleration of the limb during overhead throwing is the rotator cuff. As a brief review, the
rotator cuff is comprised of four muscles: supraspinatus, which is recruited to stabilize the humeral head, infraspinatus, which is recruited to achieve maximal external rotation and to eccentrically control forceful internal rotation, teres minor, which is similar in action to the infraspinatus, and subscapularis, which must be inhibited to also decelerate internal rotation. These muscles act as a dynamic steering mechanism for the humeral head. As a group, the rotator cuff muscles are much smaller in cross-sectional area and size when compared to the posterior deltoid, rhomboids, or trapezius. They also lie close to the center of rotation on which they act, therefore the lever arm is shorter and only a relatively small amount of force can be generated. Given this anatomical location, the rotator cuff is well situated to provide dynamic stability to the glenohumeral joint. However, it is placed at a disadvantage when called upon to generate large amounts of force, such as that required to decelerate the upper extremity during overhead throwing. This is a major reason why rotator cuff injuries are common in overhead throwing athletes.
The Role of the Core in Overhand Throwing

As mentioned earlier, the core is vital in maintaining efficiency of movement within the kinetic chain. The core’s primary function is dynamic postural control. The core also allows for the maintenance of normal length-tension and force-couple relationships to ensure optimal arthrokinematics. It helps maintain our center of gravity over our base of support as well as help keep the spine and pelvis in a neutral position during functional activities. Now let’s take a closer look at how exactly these tasks are accomplished.

The Serape Effect

Earlier, we mentioned the fact that the transversus abdominis is the muscle responsible for the initiation of all movement. We also introduced the concept of the Serape Effect which we said was a synchronized series of movements within the lumbo-pelvic-hip complex that initiates of the overhand throw. The serape is a brightly colored woolen blanket worn as an outer garment, often by people from Mexico or other Latin-American countries. It hangs over the shoulders and crosses diagonally across the front of the wearer’s body. This crossing design is
analogous to the direction of pull of a series of four sets of muscles in the same general region covered by a serape.¹¹ These muscles are: rhomboids, serratus anterior, internal obliques, and external obliques.

To build a foundation for understanding this concept, we’ll look at the functional relationship of these muscle groups bilaterally. The rhomboids have a downward and lateral orientation and attach proximally to the lower cervical and thoracic vertebrae and distally to the vertebral border of the scapula. The serratus anterior also attaches to the vertebral border of the scapula, and it continues diagonally downward as it attaches to the ribcage.¹¹ These two muscle groups work together to provide dynamic stability as well as movement of the scapula.¹¹ Continuing down the ribcage in a circular direction is the external oblique which, for our functional purposes, runs into the internal oblique on the opposite side. The internal obliques then terminate at the pelvis. When considered as a whole, there are two diagonal patterns of muscles crossing the front of the body working in conjunction with each other to produce a “muscular serape” around the trunk.¹¹

Synchronized contractions by these four muscle groups cause a series of interrelated motions within the lumbo-
pelvic-hip complex, thoracic spine, and shoulder complex during overhand throwing. The critical moving segments which produce this effect are the rotation in the transverse plane of the pelvis and lumbar-thoracic spine. The rotation at these segments takes place during the wind-up and early cocking phases of the overhead throw, as previously mentioned. The timing of these motions is critical. The Serape Effect places the body in the most efficient position to be able to use and transfer force through as many segments of the kinetic chain as possible. The abdominal and shoulder musculature is placed on maximum stretch, and the force exerted by the muscle is in direct proportion to its length-tension at the time of contraction. The muscles placed on stretch during this phase of the throw will become the force-producing muscles during the acceleration phase. If this precise sequence does not occur, maximal force cannot be produced and therefore pitch velocity decreases. The Serape Effect adds significantly to the summation of force by allowing a fluid transfer of force from the core through the spine to the shoulder complex and upper extremity.
The Role of the Scapula

As has been previously stated, the core helps maintain the pelvis in a neutral position which keeps the lumbar and thoracic spine in proper alignment. The bony link between the core and spine and the shoulder complex is the scapula. However, the exact role of the scapula has been misunderstood in many clinical situations.\(^{20}\)

The scapula serves three major functions within the shoulder complex to allow for smooth, coordinated movement. First and foremost, the scapula serves as the link in the proximal-to-distal transfer of energy that allows for the most appropriate shoulder positioning for optimal function.\(^{21}\) It is believed that efficient functioning of the shoulder and transfer of energy from the lower extremity and trunk to the upper extremity is based on this proximal-to-distal premise.\(^{14,21,22}\) The scapula provides a stable base via its articulation with the thoracic wall around which the entire arm rotates.

Secondly, the scapula maintains dynamic stability of the glenohumeral joint by moving in a coordinated fashion with the humerus.\(^{21}\) This helps maintain maximal surface contact of the humeral head within the joint. This also helps maintain normal length-tension relationships for the rotator cuff muscles, which serve to stabilize the humeral
head within the glenoid fossa. To help accomplish these goals, the scapula must at the same time provide controlled mobility. During the acceleration phase the scapula must protract in a smooth manner laterally and anteriorly around the thoracic wall to continue to move in sequence with the humerus. This is accomplished eccentrically by the medial scapular musculature, mainly the rhomboids and middle trapezius. This allows dissipation of some of the deceleration forces created during the follow-through phase.

The third major role that the scapula plays is a base for muscle attachment. The muscles that attach along the medial border of the scapula help control its position mainly through synergistic contractions and force couples. The main functions of these force couples is to ensure maximal congruency of the glenoid fossa and the humeral head and to provide dynamic stability of the glenohumeral joint. The appropriate force couples for scapular stabilization include the upper and lower trapezius working in conjunction with the rhomboids, which are paired with the serratus anterior. In addition, the muscles that attach along the lateral border provide gross movement at the glenohumeral joint. The most significant group is the rotator cuff, the importance of which has already been
discussed. As we can see, the core initiates an extremely intricate series of events in which timing and neuromuscular control is critical.

Summary

There are numerous studies available regarding both core stabilization and throwing velocity. However, fewer studies have published directly relating the two. The goal of this review is to allow the reader to examine the independent literature and make deductions about the relationship between the variables. The important concepts included in this review are the anatomy and function of the core, the mechanics of the overhand throw, and the role of the core in overhand throwing.

The core is the center of the body. It is responsible for providing dynamic postural control during functional movements. It also helps maintain normal arthrokinematics of the joints within the kinetic chain. The core serves as the center of movement for the body.

Anatomically, the core is comprised of the trunk and upper and lower extremity girdles, which are centered on the pelvis. Important abdominal muscles include the rectus abdominis, transversus abdominis, internal obliques, and
external obliques. The transversus abdominis is of particular significance as it has been shown to be the first muscle to fire when body movement is initiated. The involved back musculature includes the erector spinae, quadratus lumborum, multifidus, semispinalis thoracis, and semispinalis cervicis. The rotator cuff, trapezius, rhomboids, and serratus anterior are of primary consequence at the shoulder complex.

Many methods and devices have been designed to train the core, with varying degrees of success. It has been found that the most effective methods for training the core are the ones that mimic a crunch. Pelvic tilts have also been shown to elicit high EMG activity of the core musculature. However, crunches and tilts are nonfunctional in that they do not imitate athletic activity. Several more sport-specific core stability assessment tests have been shown to be valid and reliable measures. These include the multidirectional reach test, the star-excision test, the single-leg squat test, and the prone iso-abs test.

The overhand throw is a highly synchronized pattern of movement in athletics. It is typically broken down into five stages: wind-up, early cocking, late cocking, acceleration, and follow-through. Initiation of the movement comes from the core. The early stages of the
overhand throw serve primarily to place the body in position to maximize the use of as many kinetic chain segments as possible. This body positioning is largely due to the Serape Effect, which is a coordinated series of muscle activity within the core. When these motions occur in the proper sequence with appropriate timing, energy is transferred in a proximal-to-distal manner from the trunk and lower extremity through the spine to the shoulder complex and upper extremity. The scapula plays a key role in this process due to its articulation with the thoracic cage and the humerus. The scapula is the bony link between the core and upper extremity and is responsible for creating a stable base around which the arm rotates. It also must be mobile to move in synchronicity with the humerus to ensure optimal arthrokinematics. In addition, the stabilizing musculature of the scapula must also act to dissipate the deceleration forces created by the rotator cuff as it attempts to slow the limb down. This is essential for reducing the risk of injury while also allowing maximum pitch velocity to be generated.
APPENDIX B

The Problem
Statement of the Problem

Core training is a vital yet often overlooked point of emphasis in the strength and conditioning of overhand throwing athletes. Core muscles play a key role in trunk and pelvic stabilization during numerous athletic activities, including the overhead throwing motion. From the core, a series of movements is initiated which begins to create force production. This motion will also incorporate forceful trunk flexion and rotation, involving the core muscles to an even greater degree. The primary purpose of this study is to determine the relationship between core stability (individually comprised of functional flexibility, strength, balance, and power) and throwing velocity in overhand-throwing collegiate athletes.

Definition of Terms

The following are operational definitions of key terms for increased understanding of the study:

1) Arthrokinematics - the motion that occurs between joint surfaces.

2) Concentric Contraction - tension developed in a muscle which results in shortening of the muscle.

3) Core - (a) the lumbo-pelvic-hip complex, (b) common term used to describe the middle section of the body,
including the abdominal and low back musculature.

4) Core Stability – the collective effects of flexibility, strength, balance, and power of the core musculature.

5) Eccentric Contraction – contraction during which a muscle becomes lengthened.

6) Electromyography (EMG) – a technique of recording the electrical impulses elicited by a muscle when it activates which reveals the intensity and duration of a contraction.

7) Force Coupling – when two or more muscles simultaneously produce forces in different linear directions, although the torques act in the same rotary direction.

8) Isometric Contraction – tension developed in a muscle during which there is no change in muscle length.

9) Kinetic Chain – the soft tissue system (muscles, tendons, ligaments), nerves, and joints which work interdependently to allow for functional, efficient movement.

10) Length-Tension Relationship – the optimum length at which a muscle can exert maximum tension, lengths that are greater or less produce less tension.

11) National Academy of Sports Medicine (NASM) – governing body in the performance training field and a provider of education for fitness, sports-performance, and
sports medicine professionals

12) Serape Effect – the synchronized series of contractions within the core that stabilize and position the body during overhand throwing.

13) Stretch Reflex – the rapid stretching of a muscle which stimulates a reflex contraction of the muscle.

14) Synergist – a muscle that assists the primary muscle in creating a movement.

Basic Assumptions

The following were the basic assumptions of the study:

1) The subject sample is representative of the population of overhand throwing athletes at the NCAA Division II level.

2) The subjects have given their best effort while performing all given tasks. This has been ensured by supervision and verbal encouragement from the examiner.

3) All chosen core stability assessment tests were valid and reliable instruments.

4) The radar gun had been properly calibrated and was an accurate and valid measure of velocity.

5) All athletes were involved in similar preseason and in-season conditioning programs as is a requirement of their participation on the California University of
Pennsylvania baseball and softball teams.

Limitation of the Study

The following was the limitation of the study:

1) External validity may be compromised since the sample is limited to athletes from California University of Pennsylvania.

Significance of the study

In recent years the importance of core strength and stability has become increasingly more recognized in the world of athletics. The core plays a vital role in providing dynamic postural control during functional activities. A properly functioning core also ensures optimal arthrokinematics of the various joints within the kinetic chain. However, in the past, the focus of strength programs for throwing athletes has been on the shoulder and arm. Athletic trainers and strength and conditioning professionals are now realizing that the role of the upper extremity is only a piece of the larger puzzle. The most complete training program is one which considers this sport-specific activity within the context of the kinetic chain. Exploring the relationship between increased core strength and increased velocity in collegiate athletes will
help athletic trainers and strength and conditioning professionals in the athletic setting be better educated as to the importance of core training as well as provide them with some methods of how to improve core stability. With this knowledge, sport-specific training programs can be designed to enhance performance and prevent injury in overhand-throwing athletes.
APPENDIX C

Additional Methods
APPENDIX C1

Informed Consent Form
Informed-Consent Form

1. "Charles Green, who is a graduate assistant athletic trainer, has requested my participation in a research study at this institution. The title of the research is The Relationship between Core Stability and Throwing Velocity in Collegiate Baseball and Softball Players."

2. "I have been informed that the purpose of the research is to determine if a relationship exists between core stability and throwing velocity. I have been chosen as 1 of approximately 40 subjects because I am a baseball or softball player at California University of Pennsylvania."

3. "My participation will involve performing several functional activities which measure the components of core stability and throwing a baseball which will be measured for velocity. Each subject will be tested in one session lasting approximately 30 minutes.

4. "There is an inherent risk of injury associated with overhead throwing. I understand that I will be allowed to warm-up before participation and I will not be asked to perform a throw until I feel ready to do so."

5. "There are no feasible alternative procedures available for this study."

6. "I understand that there are several possible benefits of my participation. The results will add to the body of existing research on the subject. Participation will also allow me to have my own core stability assessed to identify areas of functional weakness that need improvement which could help to prevent injuries and improve overall athletic performance."

7. "I understand that the results of the research study may be published but that my name or identity will not be revealed. In order to maintain confidentiality of my records, Charles Green will maintain all documents in a secure location which only the student researcher and research advisor can access. All subjects participating in the study will be assigned a number which will be used for identification. Records and collected data will
be kept secure inside the researcher’s home and may only be accessible to the researcher and research advisor."

8. "I have been informed that I will not be compensated for my participation."

9. "I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by:

Charles Green  
261 California Road #316  
Brownsville, PA 15417  
724-938-6241  
gre3760@cup.edu

Dr. Bruce Barnhart  
California University of PA  
California, PA 15419  
724-938-4562  
barnhart@cup.edu

10. "I understand that written responses may be used in quotations for publication but my identity will remain anonymous."

11. "I have read the above information. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

Subject's signature __________________ Date ___________

Other signature (if appropriate) ______________ Date _____

12. "I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature."

13. "I have provided the subject/participant a copy of this
signed consent document if requested."

Investigator’s signature ______________ Date ______

Approved by the California University of Pennsylvania IRB
APPENDIX C2

Subject Information Questionnaire
Subject Information Questionnaire

Subject # ______ (For Researcher’s Use Only)

Demographic Information

Age ______

Gender   M     F

Reported height _____”

Reported weight ______ lbs.

If you have had any previous history of injury within the last six months, please place a check next to the appropriate body part.

Head ___   Trunk ___
Neck ___   Pelvis ___
Shoulder ___   Hip ___
Upper Arm ___   Knee ___
Elbow ___   Lower Leg ___
Wrist ___   Ankle ___
Hand ___   Foot ___
How many total years of experience (at all levels) do you have playing baseball/softball? ________

What position(s) do you currently play? ___________________
APPENDIX C3

NASM Functional Test Protocols
TOTAL BODY PROFILE

Overhead Squat

Objective:
To observe for total body neuromuscular efficiency, integrated functional strength
and functional flexibility

Foot and Ankle

Feet flatten (pronate): Y / N
Externally rotate (turn out): Y / N

Knees

Knees buckle inward: Y / N
Knees bow outward:

Lumbo-Pelvic-Hip Complex

Asymmetrical weight shifting: Y / N
Low back arches: Y / N
Low back rounds: Y / N
Abdomen protrudes: Y / N

Shoulder Complex

Shoulder protraction/abduction: Y / N
Shoulder elevation: Y / N
Scapular winging: Y / N

Head

Forward Head: Y / N
SINGLE-LEG BALANCE EXCURSION TEST

Objectives:
- Functional strength
- Integrated flexibility
- Neuromuscular efficiency

Foot and Ankle
  Feet flatten (pronate): Y / N
  Externally rotate (turn out): Y / N

Knees
  Knees buckle inward: Y / N
  Knees bow outward:

Lumbo-Pelvic-Hip Complex
  Asymmetrical weight shifting: Y / N
  Low back arches: Y / N
  Abdomen protrudes: Y / N

Shoulder Complex
  Shoulder protraction: Y / N
  Shoulder elevation: Y / N

Head
  Forward Head: Y / N
CORE EXERCISE ASSESSMENT

Prone Iso-Abs

Objective:
To observe the neuromuscular efficiency of the core stabilization system and the movement system of the kinetic chain.

Foot and Ankle
  Feet flatten (pronate): Y / N
  Externally rotate (turn out): Y / N

Knees
  Knees buckle inward: Y / N
  Knees bow outward:

Lumbo-Pelvic-Hip Complex
  Asymmetrical weight shifting: Y / N
  Low back arches/rounds: Y / N
  Abdomen protrudes: Y / N

Shoulder Complex
  Shoulder protraction: Y / N
  Shoulder elevation: Y / N

Head
  Forward Head: Y / N
Overhead Medicine Ball Throw

The weight of the medicine ball is not to exceed 5% of the athlete’s body weight. Begin with medicine ball in hands with arms straight. Athlete squats down and explosively jumps up and throws ball overhead (backwards for distance) simultaneously. Instruct them to release the ball in front of head. Holding on to the ball too long will cause the back to arch excessively. Measure the relative distance from starting line to point of first contact of the medicine ball.

For the purposes of this study, the best of three measured throws was used.
APPENDIX C4

Throwing Velocity Protocol
Throwing Velocity Protocol

Subjects were instructed at least one day in advance to wear athletic clothing. Subjects were given time to warm-up and/or stretch before testing began. Testing began at the subject’s discretion when they felt they were adequately prepared to throw.

Subjects were positioned at a distance not specific to baseball or softball on a flat, level surface. Testing took place at an outdoor facility at California University of Pennsylvania. Subjects were given three warm-up throws at the target before velocity measurements were taken. The subject was then instructed to throw toward the target with as much force as possible while maintaining proper body mechanics. Each subject was given three throws at the target. Each score was recorded on the master score sheet and the best of the three trials was used as the final score.

The researcher was positioned behind the target and off to the side, away from the trajectory of the ball. From this position the researcher measured throwing velocity with a JUGS™ radar gun. The radar gun was operated as instructed in the owner’s manual.
APPENDIX C5

Institutional Review Board
California University of Pennsylvania

PROTOCOL for Research Involving Human Subjects

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

☐ Request for Exempt Review
☒ Request for Expedited Review
☐ Request for Full Board Review

(Reference IRB Policies and Procedures for clarification)

Project Title: The Relationship between Core Stability and Throwing Velocity in Collegiate Baseball and Softball Players

Researcher/Project Director: Charles Green

Phone #: (724) 938-6241 E-mail Address: gree7690@cup.edu

Faculty Sponsor (if you are a student): Dr. Bruce Barnhart

Department: Health Science and Sport Studies

Project Dates: Spring Semester 2005

Sponsoring Agent (if applicable): N/A

Project to be Conducted at: California University of Pennsylvania

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

Required IRB Training

The training requirement can be satisfied by completing the online training session at http://cre.czi.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
(All Proposals Must be Typed)

1. Give a brief overview of your project/proposal with research hypothesis. I will be looking at the relationship between core stability and throwing velocity. Subjects will be asked to complete several functional tests designed by the National Academy of Sports Medicine which assess core stability, then they will be asked to throw a baseball and the researcher will measure the velocity with a radar gun. The researcher will then use SPSS to determine if relationships exist between scores for the given tests. The following are the research hypotheses:
   (1) There will be a negative correlation between functional flexibility scores (as measured by the Overhead Squat Assessment and Single-Leg Balance Excursion Test) and throwing velocity.
   (2) There will be a negative correlation between functional strength scores (as measured by the Prone Iso-Abs Test) and throwing velocity and,
   (3) There will be a positive correlation between functional power scores (as measured by the Overhead Medicine Ball Throw) and throwing velocity.

2. Give a brief description of the subjects you plan to use, and check the appropriate box(es) below. Subjects will be baseball and softball players from California University of Pennsylvania. All subjects will be volunteers. Due to the relatively small population size, all athletes volunteering to participate will be chosen to do so. The number of subjects is expected to be approximately 40.

   - Adult Volunteers
   - Minor Volunteers
   - Children Under 18
   - CAL University Students
   - Minorities
   - Disadvantaged
   - Mentally Ill
   - Elderly
   - Mentally Retarded
   - Physically Handicapped
   - Prisoners
   - Pregnant Women

3. Is remuneration involved in your project? ☑ Yes or ☐ No
   If yes, Explain below.

4. How do you plan to select subjects? Did they volunteer? Is participation required?
   Explain below.
   All subjects will be volunteers from the baseball and softball teams at California University of Pennsylvania. All volunteers will be chosen to participate in the study. Participation is not required of any athlete and subjects who wish to participate may withdraw at any time without penalty.

5. Does your project involve use of a consent form? ☑ Yes or ☐ No
   If yes, attach the form.

6. What instruments or devices will be used to gather data? Provide a copy of documentation pertaining to the data collection, such as but not limited to:
   Cover letter, questionnaire/survey, consent form, interview/focus group sheets.
   An informed consent form and a subject information form will be obtained from each subject. The subject information form will include demographic information such as age, gender, height, weight, previous injury history, total years of playing experience, and playing position. Throwing velocity measurements will be taken with a radar gun, which is considered the standard measuring tool for throwing velocity.
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 procedure.

9. The Federal Regulations require that the protocol meet certain criteria before IRB approval can be obtained. Describe in detail how the following requirements will be satisfied:

A. Insure that the risks of the subject are minimized.
   All subjects will be shown a photo of the test to be performed to help them understand the correct form. However, they will be asked to perform the test as it feels natural for them. At no time should the subjects experience any discomfort or pain during performance of the NASM tests. All subjects will also be given an adequate warm-up time prior to overhead throw testing. Warm-up times are left to the discretion of the subject. Testing will begin when the athlete feels ready. All subjects will have up-to-date physicals or physician approval before testing begins.

B. Justify the degree of risk involved (if any) in relationship to the potential of the project to the subject matter.
   The degree of risk is minimal. Each subject is a conditioned overhead-throwing athlete at the NCAA Division II level and at no time will a subject be asked to perform an activity that they would not normally perform as a member of a Division II baseball or softball program.

C. Insure that the selection of the subjects is equitable.
   All subjects will be volunteers. Because the population of baseball and softball athletes is small, all volunteers wishing to participate in the study may do so.

D. Guarantee that informed consent will be obtained for each prospective subject or the subject's legally authorized representative and that consent forms will be adequately documented.
   An informed consent form will be completed and signed by all subjects participating in the survey. A copy of the form is attached to this sheet. Each signed form will be kept in a file by the researcher and the names of subjects will be checked on a list as they are completed and turned in. Subjects who do not complete the form may not be included in the study.

E. Monitor the data collected to ensure the safety of the subject.
   Each test will be performed under the close supervision of the researcher, who is a certified athletic trainer. Improper technique or other potential injury-causing situations will be identified and corrected by the researcher to ensure that such injuries do not occur.

F. Protect the privacy of subjects and maintain the confidentiality of data.
   Subjects will be assigned a number for identification prior to participation to maintain confidentiality. The data will be collected and recorded by the researcher and will be kept in a locked file in the researcher's home. Only the researcher and research advisor will have access to the records.

G. Provide for extra safeguards to protect the rights and welfare of "vulnerable" subjects (e.g., children, prisoners, pregnant women, mentally disabled persons or economically or educationally disadvantaged persons).
   No subjects of this type will be used in this study.
Project Director's Certification
Program Involving HUMAN SUBJECTS

The proposed investigation (research or training program) involves the use of human subjects and I am submitting the complete application form and description of the project to the Institutional Review Board for Research 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 advise of the Board whenever I believe such advice is necessary would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board designed 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

Signature of Project Director

Student Research

Signature of Student Researcher

Signature of Faculty Member

Signature of Department Chairperson

***********

ACTION OF REVIEW BOARD

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.

BOARD DISPOSITION:

Chairperson, Institutional Review Board

Date 2/9/05
APPENDIX C6

Master Score Sheet
<table>
<thead>
<tr>
<th>Subject</th>
<th>Overhead Squat</th>
<th>Single-Leg Balance Excursion</th>
<th>Prone Iso-Abs</th>
<th>Medicine Ball (Best of 3 trials)</th>
<th>Pitching (Best of 3 trials)</th>
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REFERENCES


ABSTRACT

Title: THE RELATIONSHIP BETWEEN CORE STABILITY AND THROWING VELOCITY IN COLLEGIATE BASEBALL AND SOFTBALL PLAYERS

Researcher: Charles M. Green, ATC, PES

Advisor: Dr. Bruce Barnhart

Purpose: The purpose of this study was to examine the relationship between core stability and throwing velocity in collegiate baseball and softball players.

Methods: Twenty-five baseball and softball players from California University of Pennsylvania completed the study. Each athlete was asked to complete four core stability assessment tests, followed by a throwing velocity assessment which was measured using a JUGS™ radar gun.

Findings: When comparing functional flexibility and strength scores to throwing velocity, no significant relationship existed. When comparing functional power scores to throwing velocity, a strong positive correlation existed. Additional findings were also discovered. A strong relationship between height and weight and throwing velocity existed. Males were also found to exhibit higher throwing velocity scores than females.

Conclusions: There is a strong positive correlation between functional power, as a component of core stability, and throwing velocity. The results of this study would suggest that the most effective methods for strengthening the core would include dynamic power exercises that are similar in nature to dynamic power development associated with overhand throwing.