1993

Isokinetic Shoulder Strength of Women Softball Players: A Pilot Study

Karen A. Kuffel
Grand Valley State University

Diane J. Potter
Grand Valley State University

Recommended Citation

Kuffel, Karen A. and Potter, Diane J., "Isokinetic Shoulder Strength of Women Softball Players: A Pilot Study" (1993). *Masters Theses*. 149.
http://scholarworks.gvsu.edu/theses/149

ISOKINETIC SHOULDER STRENGTH OF WOMEN SOFTBALL PLAYERS: A PILOT STUDY

by

Karen A. Kuffel
Diane J. Potter

THESIS

Submitted to the Department of Physical Therapy
of Grand Valley State University
Allendale, Michigan
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN PHYSICAL THERAPY

1993

ISOKINETIC SHOULDER STRENGTH OF WOMEN SOFTBALL PLAYERS

ABSTRACT

The purpose of this pilot study was to provide isokinetic shoulder strength data on college women softball players. Ten women ranging in age from 18 to 21 years old were tested. The Cybex II+, U.B.X.T. and HUMAC system were utilized to test the strength of external rotators, internal rotators, horizontal abductors, and horizontal adductors at 90, 180, and 300 deg/sec. Mean peak torque values were consistently greater in the dominant arm but there were no statistically significant differences in agonist to antagonist ratios between arms. The ratios of external rotators to internal rotators were consistently 2:3 while the ratios of horizontal adductors to horizontal abductors ranged from 3:4 to 1:2 throughout the velocity spectrum. A weak positive correlation was found to exist between total body weight and horizontal abduction in the nondominant arm at 90 deg/sec and horizontal abduction in the dominant arm at 180 deg/sec.

ACKNOWLEDGEMENTS

A special thanks to George Sturm for his invaluable assistance with the statistical analysis for this research. Also thanks goes to Jim Scott for being so helpful and for use of equipment and the Human Performance Lab. An extra special thanks to Elizabeth Mostrom for her time and effort in helping us complete this thesis during a few chaotic semesters.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

Strength differences between agonist and antagonist muscle groups in the shoulder have been demonstrated in several populations tested in previous research.[1-4] Such differences may predispose the shoulder to ligamentous and musculotendinous injuries. If abnormal strength ratios of agonist to antagonist muscle groups are detected, then intervention with exercises to reduce the strength differences can be implemented and the likelihood of injury may be decreased. When rehabilitating an athlete after injury the clinician must be knowledgable about these strength ratios. Knowing this, they could modify the strengthening program in order to normalize strength ratios between agonist and antagonist muscle groups. This approach could prevent reinjury from occuring.

Currently, normative data regarding strength ratios of the shoulder are available for both genders.[1-4] Few researchers, however, have included female subjects in their studies on shoulder strength ratios in throwing sports. Because there may be differences in strength ratios according to more the just gender alone, more information is needed regarding the female athlete. Differences in results in this population may be due to throwing style, body composition, skeletal structure, and biomechanical factors.

We suspect that repetitive throwing may cause subtle increases in the strength of shoulder internal rotators (IRs) relative to external rotators (ERs) and horizontal adductors (HADs) relative to horizontal abductors (HABs). Considering athletes throw using their dominant arm, we expect a difference in ratios to be found between arms, with the dominant arm demonstrating smaller ratios.

The purpose of this pilot study is to provide additional documentation on peak torque of ERs, IRs, HABs, and HADs; agonist to antagonist ratios (ERs to IRs and HABs to HADs); and mean peak torque to total body weight ratios for both arms at speeds of 90, 180 and 300 deg/sec in a sample of college-aged female softball players at Grand Valley State University. In addition, peak torques for all muscle groups tested at each speed will be analyzed to determine if a correlation exists between peak torque and total body weight.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Anatomy of the Shoulder Complex

The shoulder complex is composed of three bones, the humerus, clavicle and scapula, which make up four joints or articulations. The acromioclavicular joint allows the scapula to glide forward and backward and to rotate on the clavicle.[5] This joint also functions to maintain congruency between the glenoid fossa and the humeral head.[5] The acromioclavicular joint is prone to dislocation because of the considerable movement that is available. The three supporting ligaments that function in stabilizing this joint are the conoid, trapezoid and acromioclavicular ligaments.

The sternoclavicular joint is a synovial sellar joint and is the only articulation that attaches the shoulder girdle to the axial skeleton.

The scapulothoracic joint is not considered an anatomic joint but is an important physiologic joint that adds considerable motion to the shoulder girdle. This joint is stabilized primarily by the trapezius, rhomboid major, rhomboid minor, serratus anterior and levator scapulae muscles.

The glenohumeral joint is a ball and socket joint which contributes the greatest amount of motion to the shoulder complex. The glenoid labrum deepens the articular concavity, protects the edges of the joint, aids in lubrication and serves as the attachment for the glenohumeral ligaments.[5,6] The glenohumeral joint capsule, along with anterior and posterior ligaments provide the most stabilization for this joint. In addition to the capsule and ligaments, many shoulder muscles contribute to the stability of the glenohumeral joint. The subscapularis muscle reinforces the joint anteriorly, the supraspinatus muscle reinforces the joint superiorly and the infraspinatus and teres minor muscles reinforce it posteriorly.[5] The glenohumeral joint is most unstable inferiorly because of lack of supporting structures.[5]

Kinematics and Biomechanics of the Shoulder Complex

Given the limited stability of the shoulder complex, surrounding soft tissues must help reinforce ligamentous structures. An almost perfect synergy of the shoulder musculature is required during movement because of the changing nature of the soft tissue stability.[7] The anterior, superior and posterior muscles of the shoulder have two functions. They provide the shoulder with its power and also support the humeral head. The interaction of these muscles provide effective movement and functional range of motion. The application of combined forces of synergistic muscles to produce a certain type of movement is called a force couple.[7] For example, during active abduction the deltoid muscle forces the humerus into the glenoid cavity. This movement and force is countered by the downward pull of the rotator cuff muscles on the humeral head.[7] Thus, during abduction, the greater tuberosity of the humerus is able to clear the coracoacromial arch.[7] Impingement of the rotator cuff, especially the supraspinatus, occurs if this mechanism fails to counteract the compressive force.[7] During overhead activities, if fatigue of the rotator cuff occurs, this force couple relationship may fail and cause impingement.[7]

A normal scapulohumeral rhythm is necessary for smooth overhead movement to occur.[6,7] The scapula is searching for stability on the thorax during the first 30 degrees of shoulder abduction or the first 60 degrees of shoulder flexion.[7] During overhead movements the scapula moves one degree for every two degrees of glenohumeral movement.[7] Disturbances of scapulohumeral rhythm must be addressed especially during rehabilitation after injury or surgery.

Kinematic chain relationships are defined as mechanical interactions of various anatomic joints and shoulder musculature.[7] Three of these relationships have a significant impact on sporting activities of the shoulder. The first is proximal stability, in which the shoulder girdle must remain stable while the distal components of the upper extremity are free to move.[7] The second kinematic chain is a reverse chain relationship. This occurs when the hand becomes the fixed component and the shoulder moves on or against it, for example, as in a hand-stand.[7] Cumulative actions is the third kinematic chain relationship and is defined as the summation of forces at each segment during movements of the upper extremity.[7] For example, the velocity on a thrown object is the result of the sum of the forces at each level of the kinematic chain.

Kinematics of Throwing

The act of overhead throwing is a series of rotational movements enabling the thrower to create velocity to propel the ball.[8] There are five phases that occur during a baseball pitch: wind-up, cocking, acceleration, deceleration and follow-through.[5] With the exception of wind-up, the remaining four phases are observed in throwing.

The cocking phase of throwing begins when the hands separate and ends when the arm is in full external rotation.[5,9,10] During this time, the center of gravity moves forward, the contralateral leg extends, and the opposite leg pushes off.[5] This thrusts the body weight even further forward and this phase finally ends with the contralateral foot being planted.[5]

The acceleration phase begins with the shoulder in full external rotation and abduction and ends when the ball is released.[8] The energy produced by the body's momentum is converted into arm rotation.[8] This energy transfer causes stress to be applied to the ligamentous structures in the arm. The momentum of the body produces forces that act on the humeral head pulling it anteriorly in the socket.[5] Rotator cuff muscles stabilize the humeral head during acceleration to prevent damage to the anterior labrum.[5]

After the ball is released the deceleration phase begins.[5] The forces on the glenohumeral joint are the greatest and the most difficult to control during the first 40 milliseconds of this phase.[5] During the deceleration phase, shoulder internal rotation and abduction must be reduced.[8] The shoulder adductors contract and the rotator cuff eccentrically works to accomplish this.[5,11]

Any remaining energy is dissipated during the follow-through phase.[8] The activity of the rotator cuff diminishes and there is a stretch put on the posterior shoulder structures.[5]

Functional and Clinical Implications for the Throwing Athlete

The throwing athlete appears to be among the most vulnerable to shoulder injury as a consequence of the rather violent nature of the throwing act and the repetitive nature of the stresses involved.[7] When throwing, balanced and coordinated action of the rotator cuff and shoulder musculature is paramount in providing glenohumeral stability and protection for the glenoid labrum, capsule and joint surfaces.[12] Progressive microtraumatic weakening of these structures through repetitive subluxation and mechanical impingement is felt to be a primary precursor to traumatic tearing of the rotator cuff, subsequent weakening of the muscles and ultimately abnormal imbalances between agonist and antagonist muscle groups.[7,9] Strength differences may also occur as a result of plyometric training which happens naturally in throwing.[12] This is observed when muscle groups are maximally stretched and then explosively contracted in a concentric manner, as seen with IRs and adductors (ADs) during throwing.[12] Thus these muscles become stronger than their antagonists and can cause abnormal strength ratios.[12] This may cause instability, leading to tendon or labral tears and causing poor throwing mechanics thus increasing the likelihood of injury.[1,5,8,9,13]

If abnormal muscle imbalances are shown to exist, then this information can be called to the attention of the coach and support staff so changes can be made in the strengthening and conditioning programs of athletes to correct this deficit and hopefully prevent injury.[8] But if injury occurs, the rehabilitation of the shoulder should address the stability as well as the mobility components of the musculature.[7] In the past, rehabilitation has emphasized the return of movement and mobility, but the stability component has been overlooked.[7] If both of these components are addressed, it is felt the athlete would return to function more quickly.[7]

In softball, throwing requires four primary motions at the shoulder, abduction, adduction, internal and external rotation.[5,8,13,14] Routinely, internal and external rotation has been included in the research about shoulder strength in throwing athletes, but horizontal abduction and adduction has rarely been included. A study done by Alderink and Kuck[15] was the only study containing information on isokinetic strength of horizontal abductors and adductors. Since horizontal abduction and adduction are motions that are essential in the act of throwing, it is important that they be included in the research.

Previous Research on Isokinetic Strength of Shoulder Musculature

There are many positions available to test isokinetic strength of external rotation and internal rotation at the shoulder on the Cybex II+.[16] A study by Greenfield and colleagues[17] looked at shoulder external rotation values in the plane of the scapula, which is elevation of the shoulder in a range between 30 and 45 degrees anterior to the frontal plane. The results of this study found strength values in the plane of the scapula were significantly higher than in the frontal plane.[17] In the scapular plane there is increased joint congruency, greater joint stability in the presence of a normally functioning rotator cuff and the length tension relationship of shoulder abductors (ABs) and rotators are optimum in this plane.[17] The results of Greenfield and colleagues[17] suggest that isokinetic strength training and testing may be preferable in this plane than in the frontal plane. This position, however, is not suggested for use in the Cybex II Manual.[16]

Few articles or studies have reported on shoulder strength in women.[1,3,4] Ivey and colleagues[1] included 31 people in their study between the ages of 21 and 50, with exercise levels ranging from no exercise to exercising on a regular basis. Of these subjects, 13 were female.[1] The 20 female participants in Murray and colleagues'[3] study were divided into two age groups of 25 to 36 and 55 to 66 years of age. None of these subjects were involved in heavy labor or strengthening programs.[3] The study done by Cahalan and colleagues[4] included 24 female participants between the ages of 21 and 40, who had no history of upper extremity symptoms. Normative data on shoulder strength has been gathered by several researchers[1-4] but no articles were found that measured this in women throwers. The normative data on women found external rotator (ER) to internal rotator (IR) ratios to be very similar to that reported for men.[1,4] The ratio of ERs to IRs was reported as being 2:3, but none of these articles reported values for horizontal abductors (HABs) and adductors (HADs). Several authors[12,13,15] have done studies of shoulder strength on throwing athletes but these investigators focused on male pitchers and water polo players. The ER to IR ratio was found to be 3:5 by McMaster and colleagues[13] and 2:3 by Alderink and Kuck[15] and Hinton.[12]

The literature reviewed above, used subjects with varying ages and tested both dominant and nondominant arms. The studies concerning normative data used subjects ranging in age from 21 to 66 years old, while the studies regarding throwing athletes used males in the age range of 14 to 26.[1,3,4,12,13,15] These studies also compared strength between dominant and nondominant arms. A study by Hinton[12] found that peak torque values for the throwing side IRs were significantly higher than the non-throwing side, but pitching side ERs failed to show this dominance. Also, nondominant arm ratios were reported by Alderink and Kuck[15] to be higher at all speeds and at higher functional speeds of 210 and 300 deg/sec, the throwing arm ERs were significantly weaker than the nondominant side. Ivey, McMaster, and their colleagues[1,13] found that dominant arms tended to be stronger but there were no statistically significantly differences in ratios. Cahalan and associates[4] revealed IR peak torques to be significantly greater for males and females on the dominant side, however for males this was found at speeds of 180 and 300 degrees per second (deg/sec) while for females it was found at 60, 180 and 300 deg/sec. Murray and colleagues[3] found no difference in isometric peak torques between arms therefore, noting the arm dominance of throwers is essential in order to determine whether the abnormal strength differences that are measured might have occurred due to the act of throwing itself.

The isokinetic strength of shoulder agonist and antagonist muscle groups have been measured in a variety of ranges. In the study conducted by Alderink and Kuck[15], shoulder strength for IRs and ERs was measured in the available range for each individual athlete and neither motion was reduced by range-limiting devices. McMaster and colleagues[13] limited the range of motion to 90 degrees for both internal and external rotation. The greatest range of motion allowed for rotation was in the study by Hinton[12], where internal rotation was limited to 90 degrees and external rotation was limited to 105 degrees. The Cybex II Manual[16] recommends range limitations of 90 degrees for external rotation and 70 degrees for internal rotation. In the only study including horizontal abduction and adduction, Alderink and Kuck[15] limited horizontal abduction to 90 degrees. Suggested ranges reported in the Cybex II Manual[16] were found to be 45 degrees for horizontal adduction and 130 degrees for horizontal abduction.

When doing research on isokinetic muscle strength, velocity spectrum testing is recommended.[2] A study by Alderink and Kuck[15] on college-aged baseball pitchers, tested peak torque produced by ERs, IRs, HABs, and HADs at speeds of 90,120,210 and 300 deg/sec. A statistically significant decrease in mean peak torque was found as limb velocity increased, with two exceptions.[15] The dominant arm showed no difference in peak torque for shoulder HABs between 90 and 120 deg/sec and the nondominant arm showed no difference in peak torque for ERs between 120 and 210 deg/sec.[15] Alderink and Kuck[15] reported that peak torque ratios for HAB to HAD did not statistically differ as the testing velocity increased. However, ratios for shoulder ER to IR, abductors (ABs) to ADs and flexor to extensor were statistically different when testing velocities differed by 90 deg/sec or more.[15]

McMaster and colleagues[13] tested IRs, ERs, ABs and ADs in a sample of members of the United States Men's National Water Polo Team and a control group of college-aged noncompetitive males at speeds of 30 and 180 deg/sec. The results showed that as the speeds of testing increased the agonist to antagonist ratio of ER to IR decreased.[13] A normative study conducted by Ivey and associates[1] on normal men and women between the ages of 21 and 50 tested IRs, ERs, ABs, ADs, flexors and extensors at speeds of 60 and 180 deg/sec. Ratios did not change between speeds but the peak torque values were greater at the slower speed.[1] Cahalan and colleagues[4] tested flexors, extensors, ABs, ADs, ERs and IRs isometrically and at speeds of 60, 180 and 300 deg/sec. Mean peak torque values in all planes tested were greatest when measured under isometric conditions with the exception of shoulder extension and in men only for shoulder adduction.[4] Values for mean peak torque were reported to decrease as the velocity of testing increased.[4] A study by

Hinton[12] tested ERs and IRs at speeds of 90 and 240 deg/sec and found that this ratio did not change between speeds. The recommended speeds of testing for all planes of motion at the shoulder joint are 60, 180 and 240 or 300 deg/sec, according to the Cybex II Manual.[16]

Torque to total body weight (TBW) ratios have been used to normalize peak torque data in isokinetic testing. Lean body mass (LBM) was used by Ivey and colleagues[1] to normalize data, while other researchers[2,12,15] used strictly TBW to normalize their data. Ivey and associates[1] found peak torque values were greater for men than women, but when normalized for LBM these differences became insignificant. Research by Hinton[12] revealed peak torque to TBW ratio at both low and high speeds to be significantly higher on the dominant side. The Alderink and Kuck[15] study indicated that the strongest relationship between isokinetic shoulder strength and TBW occurred at 90 deg/sec for the dominant arm only. However, shoulder ERs had a higher correlation at 120 and 210 deg/sec than at 90 deg/sec.[15] Lean body mass has been found to be more highly correlated with peak torque values than TBW.[15]

CHAPTER THREE

METHODOLOGY

This descriptive study was designed to gather information on shoulder horizontal abductors, horizontal adductors, external rotators, and internal rotators in college-age female softball players. The six primary objectives of this study were: (1) to document mean peak torque values obtained from the four motions tested, (2) calculate mean peak torque to total body weight ratios for each motion, (3) calculate ratios between agonist and antagonist muscle groups, (4) compare and contrast data recorded for the dominant arm to that of the nondominant arm, (5) report the data collected to the subject and, if authorized, to the coaching staff to alert them of any abnormal imbalances found, and (6) report the results as pertinent information to those who work with or are interested in research done on throwing athletes.

Subjects

Since women have different throwing styles, body composition, and different body mechanics than men, the sample chosen for study was Grand Valley State University's womens softball team, who were beginning their training for the current season. All players except pitchers were considered for participation in the study because of their underhand throwing style. Each participant was informed about the purpose and procedure of the testing and asked to complete a consent form. They were then screened using the tool developed by the researchers (see appendix A). This was done to ensure that all high risk candidates for injury were excluded. Candidates that were considered to have a high risk for injury were those that demonstrated one or more of the following characteristics: a previous shoulder injury within the last year, pain with any active or resisted shoulder movements, joint laxity, an unstable shoulder or one that is prone to dislocation or subluxation, swelling of the tissues about the shoulder, and limitations of range of motion greater than 15 degrees below normal in any plane as indicated by Norkin and White.[18] Subjects were recruited with permission of the team's coaching staff, the Human Subjects Review Committee and the consent of the athletes involved.

Equipment

An I.B.M. computer loaded with the HUMAC 170 system provided the program needed to execute the isokinetic tests. The upper body exercise table (U.B.X.T.) was utilized to position and stabilize the participant, and the Cybex II+ system was used to measure and record peak torque. Data was collected using the Cybex II+ system for measuring and recording peak torques. As defined by Rothstein and Lamb[19]

> Isokinetic movements require a device that provides resistance to limb movement so that a limb segment cannot accelerate beyond the machine's preset angular speed. As a result, the machine does not provide resistance, or measure torque, until the limb segment attempts to exceed the preset speed. In theory, therefore, when the limb segment achieves the preset speed and attempts to accelerate, the limb will move at a constant speed.

The Cybex II equipment was the only isokinetic device available for the researchers use on Grand Valley State University's Campus.

Positioning

The position chosen for internal and external rotation was supine on the U.B.X.T. with the shoulder abducted to 90 degrees. The U.B.X.T. was positioned so that the rotational axis of the shoulder being tested was aligned with the input shaft of the dynamometer.[16] Velcro straps were placed at the hips and under the axilla and adjusted for comfort of the subject. The researchers used the 90 degree abducted position because it most closely resembled the position of the muscles in throwing. The U.B.X.T. was positioned in supine for reasons of better stabilization of the upper body and so the gravitational forces were equal for both internal and external rotation.

Horizontal abduction and adduction were performed in supine on the U.B.X.T. with the shoulder flexed to 90 degrees and the elbow fully extended. The subject was positioned so the superior aspect of the shoulder joint lined up with the input shaft of the dynamometer. This position was utilized because of it's stabilizing features and the fact that it was the only one available for use on the Cybex II+.

Procedure

On the morning of testing the researchers calibrated the Cybex II+ using the HUMAC 70.0 program. Upon arrival for testing the participants were weighed and instructed in the testing protocol (see appendix C). In order to randomize which motion and side to begin with each subject drew a selection from a hat. There were four possibilities to begin the testing protocol with. They were: internal and external rotation on the left shoulder, internal and external rotation on the right shoulder, horizontal abduction and adduction on the left shoulder, and horizontal abduction and adduction on the right shoulder. The subject's background information was then entered into the computer while she was being positioned for the first test.

At the first testing speed, (90 deg/sec), each subject was brought through the range of motion, then given up to five warm-up repetitions to become familiar with the machine. Each participant was placed in the starting position, either full external rotation or horizontal adduction, to begin the test. They were then asked to perform six maximal repetitions and then given a 30 second rest period before moving to the next test speed.

Familiarization, warm-up and number of maximal repetitions for the second speed (180 deg/sec), was repeated as described above. At the fastest speed (300 deg/sec), a greater number of repetitions were encouraged because the program was set up as a time bout test . A one minute rest period was provided to allow for changing position to the alternate side. The aforementioned procedure was followed for the remaining test.

The recommended speeds of testing for all planes of motion at the shoulder joint were 60, 180, and 240 or 300 deg/sec according to the Cybex II manual.[16] Since testing at unnatural speeds (eg. extremely slow speeds) may lead to abnormally high joint compression loading, and may create force inhibition, the researchers used 90 deg/sec as the slowest speed and complied with Cybex recommendations of 180 deg/sec for the middle and 300 deg/sec for the highest speed.[16] The high speed of 300 deg/sec was used instead of 240 deg/sec because it is felt by the researchers that the faster speed more closely resembles the speed of throwing. Range limiting devices were used to limited internal rotation to 80 degrees, external rotation to 90 degrees, horizontal adduction to 45 degrees and horizontal abduction to 110 degrees. When setting the parameters within the HUMAC 170 system the number of repetitions for the first and second speeds were set at five and the length of time for the third speed at 15 seconds. As stated in the HUMAC 170 instruction manual,

> During an isokinetic test the initial motion of the first repetition is performed from a complete stop. All other motions are begun from an active change of direction. This can cause variations in the range of motion, time of peak torque, reciprocal delay and delay time between this initial start and the rest of the test. The HUMAC takes this into account and does not use the initial motion values for these parameters in its calculations.[20]

It is for this reason that the HUMAC system required the participant to perform an extra repetition. During the high speed test the HUMAC added an extra five seconds on to the selected time parameter because the first two repetitions tend to be sub-maximal and the subjects tend to relax toward the end of the test.[20]

Anticipated Problems, Advantages and Disadvantages with Data Collection

As with any study there were anticipated problems. If the axis of the input shaft of the dynamometer was not consistently aligned with the subject's anatomical joint being tested it may have caused uncomfortable movement through the range.[2,16] Substitution of other muscles during testing may also have been a problem.[2] If the subject was not optimally stabilized she may have substituted while testing by bending her elbow and lifting her shoulder off the U.B.X.T. This would affect the validity of the test. The fact that this study measured concentric contractions of muscle groups may also have been a problem because it has been shown that external rotators function eccentrically in throwing to decelerate the arm.[5]

The use of total body weight instead of lean body mass to normalize mean peak torque data could have been another potential problem. Alderink and Kuck[15] have suggested that lean body mass has a higher correlation with peak torque than total body weight.

In trial runs, the Cybex table was found to be unbalanced and tended to shift when maximal forces were exerted against the range limiting devices. This problem was somewhat alleviated by placing platforms beneath the uneven legs, however, some shifting still occurred during high speed testing. A final concern was the small size of the sample tested. Although we realize that further investigation with a larger sample is warranted, we hope the findings of our pilot study are not deemed insignificant due to the limited number of participants.

Advantages

There were also advantages to testing with the Cybex II+ dynamometer. The most important of these was it's safety, because of the instant accommodation it gives to pain or fatigue.[2] The Cybex II+ also provided maximal resistance throughout the velocity spectrum, was able to decrease joint compressive forces at higher speeds, and caused minimal post-exercise soreness.[2]

Disadvantages

Although the testing has been shown to be relatively safe there were two potential hazards that the researchers were aware of.[2,16] The first was that testing could exacerbate a pre-existing injury if not detected in the screening process. Secondly, an interruption in power to the speed selector device may have caused injury if it shorted out during maximal contraction.

CHAPTER FOUR

DATA ANALYSIS AND RESULTS

Ten participants were tested using the Cybex II+ and HUMAC 170 system. The data collected included peak torque for IRs, ERs, HABs, and HADs at three different speeds on the dominant and the nondominant arm. Measures of central tendency and variance (mean peak torque, standard deviation, range, and standard error) were calculated for each motion at each speed. Agonist to antagonist ratios, and mean peak torque to total body weight ratios for each arm at each speed were also reported. A paired t-test was completed to compare agonist to antagonist ratios between the dominant and nondominant arms. A Pearson correlation coefficient was calculated to determine if the relationship between mean peak torque and total body weight was statistically significant between arms.

After the data was analyzed, findings which showed significant differences in torque production of shoulder musculature were made available upon consent of the participant, to the coaches and trainers to alert them to the possibility of potential injury. This information could prove helpful for preventing injury in these athletes because special training needs could then be addressed and implemented before an injury arises.

Our population consisted of 23 members of the women's softball team at Grand Valley State University. Of these, 10 women participated in this study and comprised our final sample. Three were excluded because they were pitchers, and the other 10 did not have the coach's permission to be tested. Of the 10 participants tested, eight were right-handed and two were left-handed. The age range of the subjects was 18 to 21 years old while their weight ranged from 122 to 189 pounds.

Mean peak torque and measures of central tendency and variances for each of the four motions tested are provided in Tables 1 through 3. For all motions, mean peak torque values were greater in the dominant arm at all speeds. Mean peak torque values for HABs were greater than HADs in each subject at every speed. Throughout the velocity spectrum, as limb velocity increased, mean peak torque values for IRs, ERs, HADs and HABs decreased.

Agonist to antagonist strength ratios across the velocity spectrum are provided in Table 4. A paired t-test was used to make comparisons between ratios of dominant and nondominant arms. The difference in ratios was not found to be statistically significant for both reciprocal motions at all speeds. From 90 to 180 deg/sec, the strength differences between ERs and IRs and HADs to HABs increased, and from 180 to 300 deg/sec the strength differences between HADs and HABs continued to increase. However the difference between the mean peak torque of ERs and IRs decreased between 180 and 300 deg/sec.

Mean peak torque to total body weight ratios are given in Tables 5 through 7. A Pearson correlation coefficient was calculated to determine if a relationship between mean peak torque and total body weight existed at each of the three test speeds. In only two cases, a weak statistically significant relationship was shown to exist. These instances occurred at 90 deg/sec for horizontal abduction ($p=0.030$) of the nondominant arm and at 180 deg/sec for horizontal abduction ($p=0.031$) of the dominant arm.

The results of this study supported our hypothesis that repetitive throwing may be related to subtle increases in strength of shoulder IRs relative to ERs but did not support our idea of HADs becoming stronger than HABs. These results also demonstrated that differences in strength ratios do exist between shoulder agonist and antagonist muscle groups in both arms in our sample of female college softball players but that these differences are not statistically significant. Additionally, our research showed there is not a strong relationship between mean peak torque and total body weight with the exception of two cases, where only a weak correlation was shown to exist.

An unexpected finding was the relationship between HABs and HADs. In every participant the HABs were found to be stronger than the HADs, which was not consistent with the previous findings on male baseball pitchers.[15] In Alderink and Kuck's[15] study, the pitcher's ratios of horizontal abduction to horizontal adduction ranged from .94 to 1.04 throughout the velocity spectrum, while this study's female throwers, excluding pitchers, had ratios of horizontal adduction to horizontal abduction that ranged from .75 to .46 throughout the speeds. The ratios in females are smaller and range more throughout the velocity spectrum. The fact that every participant demonstrated higher torque production in their HABs suggests that HADs were weaker than HABs in our sample of female throwers. This finding is not consistent, however, with that found by Alderink and Kuck[15] in a sample of college-aged male baseball pitchers who showed similar strength in HADs and HABs. Strength differences in these muscle groups were also greater in the female participants than in the male baseball pitchers.

CHAPTER FIVE

DISCUSSION

For our sample of female college-aged softball players, excluding pitchers, mean peak torque values for IRs, ERs, HADs, and HABs decreased as limb velocity increased throughout the velocity spectrum. Similar results were reported by several authors.[1,4,12,13,15] McMaster and colleagues[13], however, found mean peak torque values for their control group of college aged noncompetitive males to increase as limb velocity increased.

Mean peak torque values were found to be higher in the dominant arm for IRs, ERs, HADs, and HABs at all speeds tested. These results are consistent with findings by Ivey and colleagues[1] for ERs and IRs. Studies conducted by Hinton[12], and Cahalan and his associates[4] found ERs and IRs in the dominant arm to be stronger at slow limb velocities. At high speeds ER mean peak torque values tended not to differ between arms while IRs continued to be stronger on the dominant side.[4,12] Alderink and Kuck[15] reported the nondominant ERs to be stronger than the dominant ERs throughout the velocity spectrum while the dominant IR mean peak torques were generally stronger than the nondominant IRs at all speeds in males. Alderink and Kuck[15] also revealed that the mean peak torques for HADs and HABs were stronger in the nondominant arm at the two slowest speeds and the dominant arm values were generally greater at the two highest speeds.

An unexpected finding of this research was that mean peak torque values for HABs were consistently greater than those for HADs throughout the velocity spectrum, for all participants. In their study on male baseball pitchers, Alderink and Kuck[15] reported the opposite findings. HADs produced greater mean peak torques than HABs at all speeds.[15] We believe that the results of the women softball players may have been different due to substitution of trunk muscles or underdeveloped pectoralis muscles, although no evidence of this arose from screening exam.

The agonist to antagonist ratios of ERs to IRs were approximately 2:3 at all speeds in the dominant and nondominant arms in our sample. These findings for internal rotation and external rotation were also reported by Ivey and colleagues[1], which found the ratio of ERs to IRs to also be 2:3 for high and low speeds. In the study done by McMaster and associates[13], ratios of ERs to IRs decreased as the speed of testing increased for both the control group and the water polo players. Just the opposite results were found by Hinton[12] whose ER to IR ratios increased as the limb speed increased, however these increases were not statistically significant. Alderink and Kuck's[15] study revealed similar increases in ER to IR ratios as the speeds of testing increased. These ratios were statistically different when limb speeds increased by 90 deg/sec or more.[15]

In our study the ratios of HADs to HABs ranged from 3:4 to 1:2 throughout the velocity spectrum. Strength differences between these muscle groups were greater in the nondominant arm at 90 and 300 deg/sec but were greater in the dominant arm at 180 deg/sec. Alderink and Kuck[15] found the ratios of HABs to HADs remained around 1:1 (.94 to 1.04) at all speeds. Because the ratios differ so greatly between these studies, further investigation on more and larger samples is necessary.

No statistical difference was found between the ratios of ERs to IRs and HADs to HABs from arm to arm. McMaster and colleagues[13] found that neither their control group or the water polo players showed a significant difference in ratios between right and left shoulders. The ER to IR mean peak torque ratios in the Hinton[12] study were significantly lower in the pitching shoulder compared to the nondominant side. Alderink and Kuck's[15] findings showed that ER to IR ratios were greater at all speeds in the nondominant side, while the HAB to HAD ratios were higher in the dominant arm at 90 and 300 deg/sec.

Our study found ratios for ERs to TBW and HADs to TBW decreased as speeds increased for both arms. Internal rotation to TBW ratio increased from 90 to 180 deg/sec and decreased from 180 to 300 deg/sec in both dominant and nondominant arms, however the greatest ratio occurred at 300 deg/sec in the dominant arm. The ratios for HABs to TBW on the nondominant side decreased, where as HABs to TBW on the nondominant side decreased from 90 to 180 deg/sec and increased from 180 to 300 deg/sec. Several investigators found mean peak torque to TBW ratios for IRs and ERs to decrease as the speeds of testing increased.[1,12,15] Alderink and Kuck[15] also found this to be true for HADs and HABs.

In our study, a weak correlation was found between mean peak torque and TBW in only two cases. This occurred for horizontal abduction in the nondominant arm at 90 deg/sec and horizontal abduction of the dominant arm at 180 deg/sec. The data collected by Alderink and Kuck[15] suggested that the strongest relationship between TBW and IRs and HABs occurred at 90 deg/sec for the dominant arm only. Shoulder ERs were the exception to this, where there was a higher correlation coefficient at 120 and 210 deg/sec than at 90 deg/sec.[15] Stronger correlations may have been found if lean body mass had been used instead of TBW to normalize the data because lean body mass is more highly correlated with peak torque than total body weight.

Limitations

During trial runs of this testing procedure some obstacles were encountered. Students who volunteered to run through the procedure were observed. It was found that placement of the top velcro strap around the torso allowed the volunteers to lift the shoulder off the U.B.X.T. and bend the elbow during horizontal abduction and adduction. Thus substitution with trunk muscles, (latissimus dorsi, trapezius, rhomboid major and minor) and biceps may have occurred. To help alleviate this problem, the top velcro strap was repositioned under the axilla. This aided in decreasing the problem, but a small amount of extra movement and possible substitution still occurred during actual testing. In addition to the potential for substitution, another problem encountered during trial runs was that the Cybex II+ table shifted when maximal forces were exerted against the range limiting devices. This shifting occurred because the legs were uneven causing the table to be unbalanced. Platforms were placed under the uneven legs to attempt to balance the table, but some shifting still occurred during testing. This may have influenced our results because during testing the joint angle may have changed and the energy used to move the table was not recorded as peak torque.

Limitations in regard to this data may exist because of the small sample size (N=10). Our intent was to begin raw data collection on a population who have not been previously studied, so more data will be needed to draw conclusions and generalize results to this population.

Lean body mass has been found to be more highly correlated to mean peak torque that total body weight, therefore the calculations made with TBW may be another limitation to this study's data. It would be interesting to know if stronger and more significant correlations would exist if lean body mass had been used in the calculation instead of TBW, especially since women generally have a higher body fat percentage than men.

Applications to Practice

Considering that the glenoid fossa is shallow and the glenohumeral joint contributes the greatest amount of motion to the shoulder complex, stability of this joint is critical. In addition to the capsule and ligaments many shoulder muscles contribute to glenohumeral joint stability. An almost perfect synergy of the shoulder musculature is required during movement because of the changing nature of the soft tissue stability.[7] Thus abnormal strength ratios between muscle groups need to be reduced especially around the shoulder because they also function as stabilizers for the joint.

If abnormal strength ratios are shown to exist between shoulder agonist and antagonist muscle groups it is suggested that coaching and training staff develop an exercise program to address this abnormal imbalance. This program should be individualized for each athlete and address strength and power, while focusing on reducing abnormal muscle imbalances to prevent injury. A program for women such as those in our study should concentrate on strengthening ERs and HADs to normalize strength ratios.

During the acceleration phase of throwing the momentum of the body produces forces that act on the humeral head pulling it anteriorly in the socket, if the rotator cuff muscles are not strong enough to stabilize it.[5] This anterior subluxation may cause microtraumatic tearing of the pectoralis muscle that could ultimately result in muscle weakness.[5] This is a possible explanation of why the HADs in our study were consistently weaker than HABs.

During the deceleration phase of throwing, the ERs work eccentrically to slow down the arm. A stretch is put on the posterior shoulder muscles during deceleration which may cause small microtraumatic tears to occur, and subsequent weakening of these muscles. Therefore when training throwing athletes it may be helpful to focus on eccentrically working the ERs.

Suggestions for Further Research

As a result of this pilot study's small sample size, care must be taken to avoid over generalizing from this data. More data on women throwers is needed to confirm or refute these results. Also, because there is very little normative data on women's shoulder strength, more research is needed in both areas so that in the future more inferences could be drawn about the meaning of similar research findings.

Further research needs to address peak torque values and ratios for HABs and HADs, use of splints or other equipment to control substitution, and measurement of eccentric external rotation strength. The ratios for horizontal abduction and adduction that were found in college-aged female throwers were different from those reported by Alderink and Kuck[15] for male pitchers. More research would determine if these ratios exist in other women throwers and if so, hopefully investigate why they might differ from male pitchers.

When testing horizontal abduction and adduction, bending of the elbow occurred frequently. If splints were used to prevent this, then peak torque values may be more accurate because of substitution being decreased. Currently, isokinetic machines exist that are capable of measuring eccentric strength of muscles. This is helpful to measure strength in the manner in which the muscle is contracting during an activity. Therefore, the ERs could be measured eccentrically as they function in the deceleration phase of throwing.

Conclusion

This pilot study addresses a previously uninvestigated area- isokinetic shoulder strength in college-age female throwers. An interesting finding of our research was that HADs were consistently weaker than HABs at all speeds, which is opposite of results found in male throwers. Generalizations from this data, however, should be avoided because of our small sample size. Further research is needed to investigate whether similar results would be obtained from a larger sample of college-aged women throwers.

REFERENCES

1. Ivey FM, Calhoun JH, Rusche K, Bierschenk J. Normal values for isokinetic testing of shoulder strength. *Arch Phys Med Rehabil*. 1985;66:384-386.

2. Davies GJ. *A Compendium of Isokinetics in Clinical Usage and Rehabilitation Techniques*. LaCrosse, Wis: S and S Publishers;1984:13,15,23,275.

3. Murray MP, Gore DR, Gardner GM, Mollinger LA. Shoulder motion and muscle strength of normal men and women in two age groups. *Clin Orthop*. 1985;192:268-273.

4. Cahalan TD, Johnson ME, Chao EYS. Shoulder strength analysis using the cybex II isokinetic dynamometer. *Clin Orthop*. 1991;271:249-257.

5. Donatelli RA. *Physical Therapy of the Shoulder*. 2nd ed. New York, NY: Churchill Livingstone Inc;1991:1-18, 239-270.

6. Nicholas JA, Hershman EB. *The Upper Extremity in Sports Medicine*. St. Louis, Mo: The CV Mosby Co;1990:23-38.

7. Malone TR. *Shoulder Injuries*. Baltimore, Md: Williams and Wilkins; 1988;1:84,91.

8. Abrams JS. Special shoulder problems in the throwing athlete: pathology, diagnosis, and nonoperative management. *Clin Sports Med*. 1991;10:839-861.

9. Jobe FW, Bradley JP. Rotator cuff injuries in baseball: prevention and rehabilitation. *Sports Med*. 1988;6:378-387.

10. Glousman R, Jobe F, Tibone J, Moynes D, Antonelli D, Perry J. Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. *J Bone Joint Surg*. 1988;70:220-226.

11. Silliman JF, Hawkins RJ. Current concepts and recent advances in the athlete's shoulder. *Clin Sports Med*. 1991;10:693-704.

12. Hinton RY. Isokinetic evaluation of shoulder rotational strength in high school baseball pitchers. *Am J Sports Med*. 1988;16:274-279.

13. McMaster WC, Long SC, Caiozzo VJ. Isokinetic torque imbalances in the rotator cuff of the elite water polo player. *Am J Sports Med*. 1991;19:72-75.

14. Lehmkuhl LD, Smith LK. *Brunstrom's Clinical Kinesiology*. 4th ed. Philadelphia, Pa: FA Davis Co; 1990:219-258.

15. Alderink GS, Kuck DJ. Isokinetic shoulder strength of high school and college-aged pitchers. *J Orthop Sports Phys Ther*. 1986;7:163-172.

16. Cybex: A Division of Lumex Inc. *Isolated Joint Testing and Exercise: A Handbook for Using Cybex II and the UBXT*. Ronkonkoma, NY:1983:6-13,31-46.

17. Greenfield BH, Donatelli R, Wooden MJ, Wilkes J. Isokinetic evaluation of shoulder rotational strength between the plane of the scapula and the frontal plane. *Am J Sports Med*. 1990;18:124-127.

18. Norkin CC, White DJ. *Measurement of Joint Motion: A Guide to Goniometry*. Philadelphia, Pa: FA Davis Co; 1985:138-140.

19. Rothstein JM, Lamb RL, Mayhew TP. Clinical uses of isokinetic measurements. *Phys Ther*. 1987;67:1840-1844.

20. Computer Sports Medicine Inc. *Instruction Manual for the Computer Sports Medicine Human Assessment Computer*. Waltham, Mass: 1992:1-104.

Table 1.-- Mean Peak Torques at 90 deg/sec

Variables	Mean	Std Dev	Min	Max	Std Err of Mean
ER D	12.900	2.183	10.000	17.000	0.690
ER ND	11.600	1.838	9.000	14.000	0.581
IR D	19.200	4.131	14.000	26.000	1.306
IR ND	17.300	3.164	12.000	23.000	1.000
HAB D	29.800	4.803	22.000	36.000	1.519
HAB ND	28.300	5.250	21.000	37.000	1.660
HAD D	22.400	4.575	14.000	28.000	1.447
HAD ND	20.200	3.736	15.000	26.000	1.181

ER= external rotators
IR= internal rotators
HAB= horizontal abductors
HAD= horizontal adductors
D= dominant
ND= nondominant

Table 2.-- Mean Peak Torques at 180 deg/sec

Variables	Mean	Std Dev	Min	Max	Std Err of Mean
ER D	10.800	1.398	9.000	14.000	0.442
ER ND	10.100	1.370	8.000	12.000	0.433
IR D	16.600	3.748	11.000	23.000	1.185
IR ND	15.500	3.206	10.000	22.000	1.014
HAB D	23.900	4.122	18.000	30.000	1.303
HAB ND	22.600	4.695	18.000	31.000	1.485
HAD D	15.000	3.859	9.000	20.000	1.220
HAD ND	14.500	3.440	10.000	20.000	1.088

ER= external rotators
IR= internal rotators
HAB= horizontal abductors
HAD= horizontal adductors
D= dominant
ND= nondominant

Table 3.-- Mean Peak Torques at 300 deg/sec

Variables	Mean	Std Dev	Min	Max	Std Err of Mean
ER D	8.200	1.033	7.000	10.000	0.327
ER ND	7.400	1.265	5.000	9.000	0.400
IR D	12.800	3.293	7.000	18.000	1.041
IR ND	11.600	3.502	6.000	18.000	1.108
HAB D	17.400	4.600	12.000	23.000	1.454
HAB ND	15.800	6.106	9.000	26.000	1.931
HAD D	9.300	3.917	4.000	14.000	1.239
HAD ND	7.700	4.448	3.000	16.000	1.407

ER= external rotators
IR= internal rotators
HAB= horizontal abductors
HAD= horizontal adductors
D= dominant
ND= nondominant

Table 4.-- Agonist to Antagonist Ratios Across the Velocity Spectrum

Ratios	Speeds of Testing					
	90 deg/sec		180 deg/sec		300 deg/sec	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
ER/IR D	0.682	0.085	0.670	0.116	0.671	0.144
ER/IR ND	0.677	0.075	0.665	0.095	0.688	0.224
HAB/HAD D	0.751	0.094	0.623	0.098	0.517	0.118
HAB/HAD ND	0.717	0.076	0.642	0.090	0.466	0.145

ER= external rotators
IR= internal rotators
HAB= horizontal abductors
HAD= horizontal adductors
D= dominant
ND= nondominant

Table 5.-- Mean Peak Torque to Total Body Weight Ratios at 90 deg/sec

Variables	ER/TBW	IR/TBW	HAB/TBW	HAD/TBW
Dominant				
Mean	0.026	0.054	0.134	0.110
Std Err	0.033	0.063	0.060	0.061
r value	0.265	0.291	0.621	0.537
p value	0.460	0.415	0.056	0.110
Nondominant				
Mean	0.024	0.041	0.161	0.069
Std Err	0.028	0.048	0.061	0.054
r value	0.285	0.289	0.681	0.412
p value	0.425	0.418	0.030*	0.237

* statistically significant
$p < 0.05$ is statistically significant
ER= external rotators
IR= internal rotators
HAB= horizontal abductors
HAD= horizontal adductors
TBW= total body weight

Table 6.-- Mean Peak Torque to Total Body Weight Ratios at 180 deg/sec

Variables	ER/TBW	IR/TBW	HAB/TBW	HAD/TBW
Dominant				
Mean	0.020	0.070	0.126	0.102
Std Err	0.021	0.054	0.048	0.050
r value	0.323	0.415	0.680	0.589
p value	0.363	0.234	0.031*	0.073
Nondominant				
Mean	0.022	0.043	0.126	0.061
Std Err	0.020	0.049	0.060	0.050
r value	0.351	0.299	0.595	0.396
p value	0.320	0.402	0.070	0.257

* statistically significant
$p < 0.05$ is statistically significant
ER= external rotators
IR= internal rotators
HAB= horizontal abductors
HAD= horizontal adductors
TBW= total body weight

Table 7.-- Mean Peak Torque to Total Body Weight Ratios at 300 deg/sec

Variables	ER/TBW	IR/TBW	HAB/TBW	HAD/TBW
Dominant				
Mean	0.017	0.060	0.120	0.101
Std Err	0.015	0.048	0.060	0.051
r value	0.356	0.406	0.582	0.573
p value	0.312	0.245	0.078	0.084
Nondominant				
Mean	0.006	0.025	0.132	0.054
Std Err	0.020	0.055	0.085	0.068
r value	0.100	0.157	0.481	0.271
p value	0.784	0.666	0.160	0.449

* statistically significant
$p < 0.05$ is statistically significant
ER= external rotators
IR= internal rotators
HAB= horizontal abductors
HAD= horizontal adductors
TBW= total body weight

APPENDIX A

APPENDIX A

Screening Examination

1. What is your age?
2. What position do you play?
3. Have you had an injury to either shoulder in the past year?
   If so, did it require treatment by a physician?
   Please explain.

4. Do you ever experience pain during or after throwing?
   If so please explain.

5. Which is you dominant (throwing) arm?
6. Is it possible that you may be pregnant?

PHYSICAL EXAM

1. Subject's weight -
2. Active range of motion with overpressure

	LEFT	RIGHT
shoulder flexion -		
shoulder extension -		
shoulder abduction -		
shoulder adduction -		
internal rotation -		
external rotation -		

3. Muscle tests

   internal rotators -
   external rotators -
   horizontal abductors -
   horizontal adductors -

4. Upper quarter screen

   upper trapezius (C3,4) -
   deltoid (C5) -
   biceps (C6) -
   triceps (C7) -
   thumb extensors (C8) -
   finger abductors (T1) -

APPENDIX B

APPENDIX B

Isokinetic Shoulder Strength Imbalances in College Women Softball Players Consent Form

This study is designed to obtain information regarding shoulder strength imbalances in women softball players. Data will be gathered using the Cybex II+ dynamometer to measure peak torque of agonist to antagonist muscle groups about the shoulder (horizontal abductors, horizontal adductors, external rotators, and internal rotators), following the procedures outlined in the Cybex II+ manual.

All participants will first undergo a screening process prior to testing by one of the researchers with direct supervision by a licensed physical therapist. This screen is designed to eliminate any subjects with risk characteristics. Such characteristics include the following: previous injury within the past year, tenderness upon palpation, pain with any active or resisted shoulder movements, joint laxity, an unstable shoulder or one that is prone to dislocation or subluxation, swelling of the tissues about the shoulder and limitations of range of motion greater that 15 degrees below the norm in any plane as indicated by Norkin and White.[18]

The testing procedure involves the participant being set up on and strapped to the upper body exercise table (U.B.X.T.), and after appropriate warm-up activities in this position, will be asked to perform six maximal repetitions of both internal and external rotation or horizontal abduction and adduction beginning with which ever arm and motion was randomly chosen. The participant will be asked to perform these repetitions at three different speeds.

It is estimated that the entire screening and testing procedure will take up to 45 minutes.

Immediately after the testing procedure the participant can expect to feel fatigue of her shoulder muscles. Intense activity is not recommended directly following testing.

Subjects will be given the results, and will have the option at the end of this form whether or not to disclose results to coaching personnel. Test results disclosed to coaches may be predictive of potential shoulder injury if intervention is not pursued.

If at any time the subject wishes to discontinue participation in the study she may do so.

If there are any questions concerning the procedure or purpose of the study we are willing to give further explanations.

I ______________________________, give my consent to participate in this study at my own risk. The researchers are in no way responsible for any complications or injuries incurred.

I ______________________________, do/do not (circle one) give the researchers permission to disclose the results of this study to appropriate coaching personnel.

______________________________ ________________

Participant's Signature Date

Witness Signature

Date

APPENDIX C

APPENDIX C

Instructions to Participants Prior to Testing

When the subject enters the room she will receive a brief introduction to the equipment and an explanation of the procedure as follows. "Pick a piece of paper out of this hat. This will determine which arm and test you will start with so it is randomized. This is the Cybex machine, it measures strength by how much you push against it, so the harder you push against it the more strength will be recorded. You will be tested while lying on your back on this table. These are the two motions we will be testing (demonstration). Each motion will be tested at three speeds. The slowest speed is the hardest and as the speeds get faster it is easier to push and pull. We are going to ask you to push and pull as hard as you can until you hit each bumper. Make the machine hum and hit the bumpers hard. Don't delay once you hit the bumper, go in the opposite direction right away. The person at the computer will be telling you when to go and stop, so listen for her. We are going to be yelling at you for encouragement so don't be alarmed or insulted."

Instructions to Participants During Testing

After the subject is put in position: "I'm going to use these velcro straps to stabilize your trunk for reducing substitution of unwanted muscles. In other words, try not to bend your elbow or lift your shoulder up off the table (for horizontal abduction and adduction). For example, the first movement looks like this (demonstrate the movement). I'll turn the machine on now. Go ahead and try this movement a few times to get the feel of the machine, but don't push as hard as you can, because this is just a warm up."

"When I say go, I want you to push and pull as hard as you can for six repetitions, then there will be a 30 second rest period before we change speeds. Ready?... Go!...(verbal encouragement). Okay stop. You can rest now."

"I've changed the speed now. You'll be able you move your arm faster this time. Take a few practice repetitions just to get used to the new speed. When I say go remember to push and pull as hard as you can. Ready?... Go!... (verbal encouragement). Okay stop. You can rest now."

"I've changed the speed to go even faster. This will be harder to keep up with but try as hard as you can. Go ahead and take your practice repetitions. When I say go push and pull as hard as you can. You will have a one minute rest while we reposition the table to test your other arm." The instructions will be repeated for the other arm.

Once the testing of the first motion is completed, "You can just lie there and rest now while the report is being printed and we reposition the machine for the other motion.

This will take about five minutes." Repeat instructions for the remaining motion.

AUTOBIOGRAPHICAL STATEMENTS OF AUTHORS

Diane Potter is from the small iron mining town of Palmer in the Upper Peninsula of Michigan. She is a 1986 graduate of Negaunee High School and a 1990 graduate of Northern Michigan University in Marquette, where she earned a Bachelors Degree in Biology.

Karen Kuffel was born in Macomb, Illinois, but was raised in Escanaba, Michigan and graduated from Escanaba Area High School in 1986. She went on to complete her Bachelors Degree in Biology at St. Norbert College in DePere, Wisconsin, where she also met her husband Matthew.

This study was completed by the authors in partial fulfillment of the requirements for the degree of Master of Science in Physical Therapy, Grand Valley State University.