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The Effect of Left Pelvic Positioning on Contralateral Shoulder Total Range of Motion and Internal Rotation Deficit in Collegiate Baseball Pitchers

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Abstract

The Effect of Left Pelvic Positioning on Contralateral Shoulder Total Range of Motion and Internal Rotation Deficit in Collegiate Baseball Pitchers

Context: Shoulder injuries are a significant problem in baseball players. The relationship between shoulder range of motion (ROM) deficit, hip joint flexibility and function of the diaphragm has been investigated as a global contributor to injuries in overhead athletes. **Objective:** To investigate the effects of pelvic positioning on shoulder total ROM and IR, and contralateral hip internal rotation (IR) of baseball players. **Design:** Pretest/posttest observational cohort study with repeated measures **Setting:** NCAA Division II baseball team **Patients:** Ten male pitchers **Intervention:** Left hip repositioning technique **Main Outcome Measure(s):** ROM was assessed using a digital inclinometer for right shoulder IR, right shoulder total ROM, left hip IR, and presence of left anterior inferior chain (AIC) pattern. **Results:** During the 5-day intervention, 6 pitchers presented without the left AIC pattern, while 4 presented with the left AIC pattern in up to half of the 10 encounters. The results of a one-way ANOVA with repeated measures indicated a significant time effect for both left hip internal rotation and shoulder total motion. A one-way ANOVA with repeated measures indicated no significant time effect for shoulder internal rotation. There were no between group differences in any range of motion when comparing LAIC pattern to a neutral pelvis. **Conclusions:** Participants experienced changes in ROM as a result of regular throwing per prior research. However, the left AIC pattern did not occur as frequently as hypothesized; therefore, the effects of left pelvic positioning on shoulder and hip ROM are unclear. **Word Count:** 243

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Chapter 1: Literature Review

INTRODUCTION

Upper extremity injuries, especially in the shoulder and elbow, are a significant problem in baseball players.[1] These injuries cannot be attributed to a single factor, rather there are many confounding factors which can be broadly categorized as intrinsic and extrinsic. An exhaustive review of all factors is beyond the scope of this literature review. This review will detail intrinsic factors which are specific to the shoulder joint, including lack of internal or external rotation, osseous adaptations, soft tissue changes[1-4] and associated factors including adaptations in hip range of motion[5], impaired breathing patterns[6], and postural asymmetries.[7-9]

For many years the physical adaptations that occur in the shoulder as a result of repetitive throwing has gained substantial attention.[1,10-12] In fact, improving shoulder range of motion has shown to be an effective injury prevention strategy.[3] More recently, the relationship between shoulder range of motion deficit, hip joint flexibility and function of the diaphragm has been investigated as a global contributor to injuries in overhead athletes. However, this relationship has yet to be studied in the baseball population.

PHYSICAL ADAPTATIONS OF THE THROWING SHOULDER

The kinetics and kinematics of overhead throwing has long been studied and continues to be by researchers around the world. The excessive stress placed on the glenohumeral joint and surrounding tissues during the overhead throwing motion often go beyond physiologic limits and may lead to morphological changes or injury.[10] Wilk, et al states that at the point of maximum external rotation there is upwards of 60 Nm of torque placed on the shoulder.[11] This amount of torque repetitively placed on the shoulder is thought to largely contribute to overuse injuries in baseball players.[11] As a result of the repetitive forces on the shoulder, especially at maximal cocking phase, excessive external rotation of the glenohumeral joint is observed.[11] In turn, most overhead athletes will also present with decreased internal rotation (IR) at the glenohumeral joint[10,11,13], otherwise referred to as Glenohumeral Internal Rotation Deficit (GIRD).

Quantifying Loss of Shoulder Range of Motion to Understand Injury Risk

As stated, a loss of glenohumeral IR is an adaptive implication of repetitive overhead throwing. While this is a known implication that has been observed for a long time, quantifying the deficit in motion has been viewed differently by researchers.

Internal Rotation Deficit. One school of thought regarding a change in range of motion in the throwing shoulder is the concept of GIRD. Burkhart, et al originally reported that GIRD was an IR deficit of more than twenty degrees when compared to the non-throwing shoulder.[14] They provided a possible explanation for this lack of IR by stated that the posterior cuff becomes hypertrophied and in a state of contracture due to the eccentric forces of throwing.[14] Furthermore, Keller, et al conducted a systematic review and meta-analysis that synthesized seventeen articles regarding GIRD. Their results showed that a greater amount of IR deficit may have a negative effect on the throwing shoulder.[15] Their discussion also connected GIRD with the total range of motion concept by saying that an increase in total range of motion may protect the throwing shoulder from injury, while a decrease in total range of motion may be detrimental.[15]

Total Range of Motion Deficit. Total Motion (TM) summates both internal rotation and external rotation.[11] One method of quantifying glenohumeral range of motion loss is by assessing TM in the throwing shoulder, as described by Wilk, et al, and comparing that value to the TM in the opposite shoulder.[11] A systematic review done by Bullock, et al showed that a pool-analysis of six articles that studied shoulder range of motion in injuries concluded that a

TM deficit of more than five degrees increased the chance for shoulder injury.[1] In addition, Wilk, et al found that pitchers who had a TM deficit of greater than five degrees compared to their non-dominant shoulder, were at approximately 2.5 times greater risk for injury.[11]

In addition to an increased risk of injury, a TM deficit has also been found to decrease muscle strength.[16] In a study of 193 pitchers, a correlation between a decreased total arc of motion and decreased shoulder abduction strength was statistically significant.[16] This study suggested that decreased TM may be responsible for a shoulder strength deficit, which may also lead to injury.

On the contrary, Wilk et al, researched professional baseball pitchers over eight consecutive seasons to establish a relationship between total range of motion and injury statistics.[2] They found a significant difference in TM as well as shoulder flexion in the throwing arm versus the non-throwing arm in every pitcher.[2] They also found that TM was a significant predictor of injury or surgery over the eight seasons. Though they found that insufficient glenohumeral external rotation was a more significant predictor of shoulder and elbow injuries.[2]

Humeral Changes

Although there is no definitive physiological explanation for why GIRD occurs in the throwing athlete, there are multiple theories explained by researchers. Reagan, et al reports that osseous adaptations occur in the shoulder girdle as a result of the extreme, repetitive stress that encompasses overhead throwing.[17] Pieper originally described an osseous adaptation as humeral retroversion or retrotorsion.[18] He defined this as the angle between the elbow joint axis and the axis of the humeral head.[18] In his study, Pieper found that the humerus of the throwing shoulder of handball players was, on average, retroverted 9.4 degrees more than the non-dominant humerus.[18] A few years later, Reagan, et al took this same concept and applied it to a study

regarding humeral retroversion in collegiate baseball players. This provided baseline data on retroversion seen in this population, which was, on average, 10.6 degrees greater compared to the non-dominant arm.[17] Crockett, et al continued this theory of research and found that professional baseball pitchers also had significant humeral retroversion in their dominant arm. In addition, they also found that the glenoid cavity was significantly retroverted in the dominant arm.[19]
To help further correlate humeral retroversion and GIRD, Noonan, et al studied professional baseball pitchers with and without GIRD. This studied confirmed that pitchers who presented with GIRD had a statistically significant increase in humeral retroversion of an average of 5.9 degrees. Although previous studies also found these results, Noonan, et al had the largest sample size and was prospective over four professional baseball seasons.[20]

It is thought that humeral retroversion correlates with the age in which a person begins playing baseball. However, it was found that Major League Baseball players from Latin America, on average, started playing at a later age (nine years old) as compared to North American players (five years old). Contrary to this popular belief, the Latin American players displayed greater humeral retroversion in their dominant or throwing arm. However, total shoulder range of motion was approximately the same between the two cultural groups. This leads researchers to believe that Latin American players adapt through osseous changes and North American players adapt through the soft tissue.[21] As a whole, these studies suggest that overhead throwing causes osseous adaptations specifically to the glenohumeral joint, which may assist in explaining the glenohumeral IR deficit seen in overhead athletes.[17-21]

THE RELATIONSHIP BETWEEN LUMBOPELVIC-HIP COMPLEX AND SHOULDER

Although understanding and treating the glenohumeral joint is commonly focused on in the throwing athlete, the lumbopelvic hip complex is also an integral aspect of overhead throwing. Fluidity and specific coordination of the entire kinetic chain in the body, especially the lumbopelvic hip complex, is crucial for overhead throwing.[22] The lower extremities produce force that must be transferred up through the body all the way to the hand releasing the ball; whereas, the lumbopelvic hip complex is the connection between lower and upper extremities.[22] Robb, et al described this transfer of force as being approximately 1.75 times the bodyweight of the pitcher that starts in the lower extremities and moves through the hips to the trunk.[23]

The Lumbopelvic-Hip Complex in Baseball Players

Repetitive stress is placed on the hips just as there is repetitive stress placed on the shoulder in overhead throwing. As a result, baseball players may form a variety of adaptive changes in their lumbopelvic hip complex[24] possibly throughout a season and over the course of their baseball career. Zeppieri, et al aimed to observe changes in hip range of motion and strength longitudinally over one competitive season.[25] Their participants consisted of fourteen NCAA Division I baseball pitchers, both left and right-handed. They observed that hip internal and external rotation of both the lead and trail legs of the pitchers significantly decreased over the span of the season.[25] It is speculated that these changes may occur because of the excessive IR of the lead leg during the beginning phases of the pitching motion as well as excessive landing of the lead leg in an internally rotated position.[25] This was the first study that was longitudinal in nature that suggests the mechanics of baseball pitching is related to adaptations in the lumbopelvic hip complex. Conversely, another study on adolescent baseball players found that there are no changes in hip rotation as a response to decreased range of motion at the shoulder. Furthermore, an increase in trunk rotation has the potential to cause shoulder pain as well as shoulder pain may cause an increase in trunk rotation.[26]

In addition to disparities seen in pitchers, Laudner, et al hypothesized that there may be differences between the positions in baseball. They measured hip internal and external rotation as well as gluteus medius strength of forty professional baseball pitchers and forty position players. Their study found that position players had greater IR and gluteus medius strength in their trail leg compared to the pitchers.[24] The authors speculated the reason behind a difference and credited the slope of a pitching mound as giving pitchers momentum; therefore, they would not need to develop as much strength in the gluteus medius compared to a position player throwing on flat ground.[24]

Effect of Lumbopelvic-Hip Complex on Performance

Since it is known that the lumbopelvic hip complex is a crucial part in the kinetic chain, some researchers have focused on connecting it with throwing mechanics. Two important aspects of throwing mechanics are torque placed on the glenohumeral joint and elbow along with maximum velocity. It has been found that a lack of lumbopelvic control increases the horizontal abduction torque on the shoulder and valgus torque at the elbow.[5] There is no universally accepted way to characterize lumbopelvic hip instability, but the anterior to posterior tilt of the pelvis during a single leg balance test was used by Laudner, et al. Laudner, et al also found that decreased hip range of motion was correlated with increased torque at the shoulder.[27] In addition, they found that decreased hip external rotation was related to an increase in horizontal adduction during the throwing motion. This supports the idea that players throw "across their body" possibly leading to an increased risk for injury.[27]

Furthermore, research has shown that core stability may be associated with an increase in maximal velocity. Saeterbakken, et al found that a specific core sling exercise program increased velocity of female handball players by approximately five percent of their baseline velocity. An increase in velocity may be attributed to lumbopelvic hip stability as well as rotational strength developed in the core.[28] Similarly, it has been found that lumbopelvic hip instability may have a negative impact on segmental speeds of the body during throwing.[29] Also using female handball players, it was observed that those who had an unstable pelvis, characterized by knee valgus of more than seventeen degrees, had slower segmental speeds than those considered stable. In other words, maximal velocity decreased as a result of a slower rotational speeds at the shoulder ultimately due to losing kinetic energy at the unstable pelvis.[29] However, this type of study and results have not been found in male baseball players so this correlation is only speculation at this point in time.

Effect of Lumbopelvic-Hip Stretching on the Shoulder

In addition to lumbopelvic hip stability, optimal mobility in this region is also important in the overhead athlete. One method of trying to decrease GIRD involves a self-induced IR stretch commonly called the "Sleeper Stretch". However, stretching at the contralateral sacroiliac joint was proven to be more effective at restoring IR post-throwing. Contractures at the sacroiliac joint affecting the shoulder is still a relatively upcoming research area, but this study involving minor league baseball players may help prove that there is a something other than contractures affecting hip and shoulder range of motion short term.[30]

BREATHING PATTERN DISORDERS

Breathing pattern disorders are a rapidly expanding topic, especially in athletes and the active population. First, breathing pattern disorders are not well defined in the medical world, but a common description is 'Inappropriate breathing which is persistent enough to cause symptoms, with no apparent organic cause'.[31] Multiple factors can cause or affect breathing pattern disorders and musculoskeletal imbalances are one of them.[6,32] The presence of a breathing pattern disorder can be a sign of coexisting mechanical, physiological or physical problems in the body.[32] Over time, the presence of a breathing pattern disorder can alter the resting position of surrounding muscles. This includes the rectus abdominis and oblique muscles have an increased resting tone.[6]

Breathing Pattern Disorders in Functional Movements

As a result of affecting the resting and dynamic positions of muscles, breathing pattern disorders have also been shown to affect functional movement. Bradley and Esformes found that those who presented with an abnormal breathing pattern, characterized by thoracic breathing, scored lower on the Functional Movement Screening test. More specifically those who were considered diaphragmatic breathers, on average, scored higher on the Functional Movement Screening than those considered thoracic breathers. Thoracic breathing is considered disordered and less efficient; therefore, this proves the importance of diaphragmatic breathing especially in exercises.[33] It has been summarized that if a normal breathing pattern is not present, then no other movement pattern will be normalized.[34]

Breathing Pattern Disorders and the Shoulder

An atypical breathing pattern causes respiratory accessory muscles to be in an altered state and length. Two of these accessory muscles, the trapezii and pectoralis minor, are often affected[32] and are two key muscles used in overhead throwing. However, these two muscles are not the only ones used in overhead throwing that are affected by breathing pattern disorders. In fact, there are many respiratory muscles that attach to the scapula and affect scapular positioning.[6] It has been shown there is a positive correlation between the Manual Assessment of Respiratory Motion and a scapular dyskinesis test of the non-dominant limb.[6] This correlation means that the presence of a breathing pattern disorder may coexist with the presence of scapular dyskinesis in the non-dominant limb. A correlation between these two tests for the dominant shoulder proved to not be statistically significant.[6]

THE ASYMMETRICAL HUMAN BODY

Naturally occurring asymmetries in the human body can affect muscle and movement patterns. These asymmetries may affect movement patterns but are also caused by those same movement patterns that include the bones, muscles and joints of the body.[9] Patterns of muscular activation and asymmetry in turn create differences in the body, specifically between the left and right sides.[9]

Left Anterior Interior Chain Pattern

As stated before, the pelvis is a crucial link between the lower and upper extremities in overhead throwing. In addition, the pelvis is also the site for one of the most common and influential asymmetries in the body. The difference is seen in the left hemipelvis being anteriorly tilted and forwardly rotated accompanied by a rightly positioned sacrum and lumbar spine.[9] Hruska has labeled this pattern as Left Anterior Interior Chain (LAIC) pattern.[9] Since an asymmetry in the bones and joints exist, muscle activation will not be equal and will also be needed in an attempt to bring the bones and joint back to center.[9] In overhead throwers specifically, these changes affect force production and alter the whole kinetic chain throughout the throwing motion. For example, proper rotational movement at the hips is needed during the throwing motion. However, LAIC pattern usually presents with limited range of motion accompanied by tight internal rotators on the dominant/trail leg and tight external rotators on the non-dominant/lead leg.[9] Tightness in these muscle groups inhibit proper rotational movement in the lumbopelvic hip complex and may increase chance of injury somewhere else in the kinetic chain.

Effect of LAIC Pattern on the Scapula

The positioning of the scapula on the thorax is typically affected by these side to side discrepancies in the body. When observing a patient that prevents with a LAIC pattern, their thorax and lumbar spine will appear side-bent to the right which will cause the right shoulder to appear lower compared to the left.[8] As a result, the resting position of the scapula is more adducted/depressed on the thorax as well as upwardly and internally rotated. This position may be observed as a “winging” scapula.[8] An overhead athlete that presents with this pattern will have to compensate somewhere in the kinetic chain in order to allow the proper axis of rotation in the glenohumeral joint. This compensation usually occurs by abducting and elevating the scapula. In addition, this anterior resting position of the scapula also allows more external rotation and less IR at the glenohumeral joint because of the altered position of the glenoid.[8] The change in resting position and thus muscle firing patterns due to the LAIC pattern may play a role in the myokinematics of injury in overhead athletes.

The Adduction Drop Test

The asymmetries of the human body as described by Hruska can be easily identified with a common special test. It is similar to the Ober’s test, originally used test the tightness of the tensor fascia latae muscle and iliotibial band.[35] According to the Postural Restoration Institute® (PRI) the Ober’s test is a better indicator of how the femoral head is interacting with the acetabulum of the pelvis. The PRI® refers to this as the Hip Adduction Drop test. To perform the test the patient is side lying on the non-tested side with their pelvis stacked on top of one another. The hip that is in contact with the table (not being tested) is flexed to 90 degrees with the knee also flexed to 90 degrees to ensure the is oriented perpendicularly to the table. The examiner instructs the patient to relax and proceeds to passively abduct and extend the top hip.

If the femur is centrally located in the acetabulum, indicating a "neutral" position, the top hip will drop so that the knee contacts the table, resulting in a negative test. A positive test, or non-neutral pelvis, occurs when the top hip fails to drop to the table. A positive test indicates that the femoral head is positioned inferiorly in the acetabular cavity which prevents the femur from fully adducting, in turn limiting hip adduction range of motion.[36]

The PRI® has created neuromuscular training exercises which aim to normalize the position of the pelvis.[37] All of the exercises involve targeted co-contractions to the pelvis musculature, in attempt to overcome the patterns of the LAIC discussed previously. While there are numerous exercises that target specific components of the LAIC pattern, only one will be described in detail as it is commonly utilized.

Hemibridge exercise. In the hemibridge with ball exercise the patient lies on a table with their feet flat against a wall, knees and hips both at a 90 angle with a ball in between their knees while holding a standard balloon in their mouth with one hand. The right arm is placed in a flexed position next to the head, which allows the right superior lobe of the lungs to be in a more optimal position during the exercise. Simultaneously keeping the left arm down helps to keep the ribs down. The supine position with the hips and knees at 90 degrees on the wall forces the lumbar spine into flexion with a posterior pelvic tilt. This position is reinforced when the athlete contracts their hamstrings and gluteus maximus. Squeezing the ball in between the knees activates the hip adductors to help reposition the pelvis back to neutral. The 90-90 position of the knees and hips also depresses the ribs to optimize the position of the diaphragm. Blowing up the balloon activates the abdominal muscles strictly as rib stabilizers to assist in keeping the diaphragm in an optimal position for both respiration and postural control. The resistance provided by the material of the balloon requires the intercostal muscles needed for all cycles of respiration to lengthen and contract.[38]

Effect of hemibridge exercise on the shoulder. Nourkbasch, et al used this hemibridge exercise from the PRI® and compared it to a standard exercise program aimed at increasing hip mobility to see how the two regimens affected shoulder range of motion and torque. The hemibridge pelvic repositioning technique was more effective at creating a normal/neutral pelvis compared to the dynamic hip mobility exercises. This pelvic repositioning technique has also been successful at immediately influencing the modified Ober's test by increasing hip adduction as well as decreasing pain in the lumbopelvic area.[36,39] More importantly, they found that realigning the pelvis via the hemibridge exercise was more effective at increasing glenohumeral IR at the contralateral shoulder. In fact, GIRD decreased approximately 95% in the contralateral shoulder after the pelvic repositioning.[37]

While these results are promising, two limitations to the study exist. First, this study was conducted in healthy subjects, meaning they were not said to have GIRD. Second, physically active college-aged students, not athletes, were included in the sample. Thus, the purpose of this study is to investigate the effects of pelvic repositioning on shoulder total range of motion and IR, and contralateral hip IR of baseball players.

Chapter 2: Methods

Study Design

This study was a pretest/posttest observational cohort study with repeated measures, that required a specific population of baseball athletes; therefore, the West Chester University (WCU) baseball pitchers were the convenience sample chosen to be utilized. Upon receiving WCU IRB Approval (Appendix 1), permission from the WCU Head Baseball Coach to conduct the study was granted (Appendix 2), and the primary researcher attended a team meeting to recruit participants.

Participant Selection

During the meeting, the prospective participants were given a summary of the study and the details of the study. Players who signed the informed consent form (Appendix 3) proceeded to fill out the health history questionnaire (Appendix 4). This questionnaire asked participants to disclose previous injuries that they have ever sustained, had sustained within two years, and had sustained within three to six months. The only inclusion criterium was that participants had to be a pitcher-only athlete on the spring 2020 roster. Participants who were excluded from the study were those who had hip or shoulder surgery, history of ulnar collateral ligament repair or reconstruction (Tommy John surgery), had a diagnosed, untreated labrum or rotator cuff tear, and/or had an acute oblique strain. Exclusion criteria was ultimately determined by injuries disclosed on the health history questionnaire.

Outcome Measures

The main outcome measures of this study were contralateral shoulder total range of motion and contralateral shoulder IR. In addition, hip IR was a dependent variable assessed throughout the study.

Assessing Range of Motion. A standard digital inclinometer was used to assess shoulder and hip ranges of motion. For shoulder rotation measurements the patient was supine with their shoulder at ninety degrees of abduction and their elbow at ninety degrees of flexion. A research assistant stabilized the scapula via the coracoid process while the examiner measured range of motion. Passive range of motion with stabilization at the coracoid is a reliable way to measure true rotation at the shoulder and therefore was used.[11] The participant sat on the edge of a table with their hips and knees at 90 degrees hanging off the table. Hip IR was actively measured by the clinician. The Postural Restoration Institute® suggests active hip range of motion and therefore that method was used.[40]

Testing Procedures

Before each practice, participant's femoral acetabular position was assessed via the Hip Adduction Drop test (Appendix 5). The outcome of this test was used to determine the need for repositioning of the pelvis before activity. Hip position was then assessed again after activity to show any changes that may have occurred.

Pelvic Repositioning. Participants who presented with a positive Hip Adduction Drop Test completed the the 90-90 Hip Lift with Hip Shift pelvic repositioning exercise, created by the PRI® (Appendix 6).[38] In this technique, the patient was supine with their hips and knees at 90 degrees on a wall. A four to six-inch ball was placed in between the knees. A pelvic tilt was performed as the patient inhaled and exhaled deeply, bringing their tailbone slightly off the table. While keeping the hip lift, the patient was instructed to position their left leg slightly below their right leg. The right knee then sat higher than the left. The right leg was moved on an off the wall for ten repetitions. During this pattern of movement, the patient was expected to feel their left hamstrings and left adductors activating. The goal of the co-contracture of these muscles was to bring the femoral head back into the optimal position in the acetabulum.[40]

Data Collection Sheets. All baseline, intervention, and post-intervention data were recorded on collection sheets throughout the study (Appendix 7). The baseline data sheet included an estimation of the participant's self-reported height and weight. The outcome of the

Left and Right Hip Adduction Drop tests and all range of motion findings were recorded on all data sheets.

Intervention Schedule

The intervention period lasted 5 consecutive days during the second week of the competitive season. Baseline measurements were taken approximately four days prior to the intervention period; whereas, the post-intervention day was approximately 2 days after the intervention period ended. The participants were asked to report before and after practices each day.

Baseline Measurements. Prior to the study being conducted, the following baseline measures were assessed: height and weight estimations, bilateral shoulder rotation measurements, hip IR measurements, and a hip adduction drop test. Participants were also asked to disclose their dominant hand and their throwing arm on the previous health history questionnaire.

Pre-practice Procedures. An algorithm/flow chart was created to show the data collection procedures (Appendix 8). It began with the left hip adduction drop test followed by the right adduction drop test. If either of the adduction drop tests were positive, the participant was then repositioned with the 90-90 Hip Lift with Hip Shift exercise. Following reposition, the adduction drop test was done again to confirm repositioning was successful by observing a negative test. If the participant had negative adduction drop tests bilaterally, there was no need to reposition, as the pelvis is already considered neutral. These participants were immediately sent to practice. This algorithm was used every day for five consecutive days of data collection (Monday through Friday).

Post-practice Procedures. After baseball practice, the clinician gathered the participants and collected post-practice measurements. The hip adduction test was done again as well as shoulder range of motion and hip range of motion. These measurements were taken immediately after practice in the athletic training room to ensure that all participants were measured post-practice every day.

Post-Intervention Measures. Approximately one week from the first day of data collection, the following Monday, measurements without the intervention were taken. The clinician performed the hip adduction drop test, bilateral shoulder range of motion measurements, and hip IR measurements. These measurements were taken after practice, but the repositioning technique was not performed prior to practice.

Chapter 3: Results

Participants

Eleven pitchers met the criteria for this study. One participant dropped out and was further excluded from the study. Therefore, 10 participants completed the study in full. Seven were right-handed and 3 were left-handed. Two participants were true starting pitchers, while eight were relievers. All participants engaged in pre-season activities per the coach's schedule. Nine of the participants threw 2-3 bullpens within the data collection period. Some participants who threw a bullpen also threw live at-bats at least once.

Statistical Analysis

Prior to analyses, participants were categorized as having a neutral pelvis versus a non-neutral pelvis. This was determined by the presence of a left AIC pattern or having a positive left hip adduction test at some point during the intervention period. Those that always had a negative left hip adduction test were considered the neutral pelvis group.

Table 1 reflects whether the adduction drop test was positive or negative for the left hip at baseline, the number of times the participant had a positive hip adduction test throughout the intervention period, and at the end of the intervention. The table was used to determine the neutral pelvis and non-neutral pelvis group based on the column displaying the number of times they were positive during the intervention period. If this column reflected a number other than 0, the participant was categorized as non-neutral.

Table 1. Results for Hip Positioning

Participant #	Baseline Left Hip Adduction Test	# of times Left Hip Adduction Test Positive During Intervention	Post-Intervention Left Hip Adduction Test
1	Negative	0/10 (0%)	Negative
2	Positive	0/10 (0%)	Negative
3	Positive	1/10 (10%)	Negative
4	Negative	1/10 (10%)	Negative
5	Positive	0/10 (0%)	Negative
6	Positive	1/10 (10%)	Negative
7	Negative	0/10 (0%)	Negative
8	Negative	0/10 (0%)	Negative
9	Negative	5/10 (50%)	Positive
10	Negative	0/10 (0%)	Negative

Range of Motion Findings

Shoulder IR, TM and left hip IR range of motion measurements were taken at baseline, after practice, and on the post-intervention day. The percent change in range motion from baseline to post-intervention is reflected in Tables 2, 3 and 4.

Shoulder Internal Rotation ROM

Overall, 7/10 (70%) of the participants gained shoulder IR ROM throughout the study. At baseline, 2/10 (20%) of participants were observed to have GIRD (>20 degrees difference bilaterally).[14] Post-intervention measures showed that no participants (0/10) were categorized as having GIRD. Percent change in IR ranged from 6.9% to 48.1%.

Table 2. Right Shoulder Internal Rotation Change

Participant #	**Baseline Right Shoulder Internal Rotation, degrees**	**Post-Intervention Right Shoulder Internal Rotation, degrees**	**% Change in Range of Motion**
1	29.9	23.1	-22.7
2	29.2	34.0	16.4
3	28.0	36.5	30.4
4	38.2	29.4	-23.0
5	44.3	41.0	-7.4
6	33.2	35.5	6.9

7	37.8	56.0	48.1
8	25.2	32.4	28.6
9	30.0	34.4	14.7
10	47.8	53.1	11.1

Shoulder Total Motion (TM)

Overall, 10/10 (100%) of the participants had an increase in shoulder total motion. TM is considered ideal by comparing bilaterally. The percent change in total motion varied from 7.6% to 34.7%.

Table 3. Right Shoulder Total Motion Change

Participant #	**Baseline Right Shoulder Total Motion, degrees**	**Post-Intervention Right Shoulder Total Motion, degrees**	**% Change in Range of Motion**
1	105.2	118.5	12.6
2	98.3	117.8	19.8
3	113.2	132.6	17.1
4	114.9	123.6	7.6
5	122.2	135.5	10.9
6	104.7	111.4	6.4
7	101.0	136.0	34.7
8	115.1	132.4	15.0

9	102.5	128.6	25.5
10	122.0	140.8	15.4

Hip Internal Rotation

Overall, 9/10 (90%) of the participants had an increase in hip IR. All participants (10/10) lacked hip range of motion at baseline. However, all participants (10/10) saw an increase in hip range of motion over the course of the intervention period. Percent change ranged from 6.0% to 69.7%.

Table 4. Left Hip Internal Rotation Change

Participant #	Baseline Left Hip Internal Rotation, degrees	Post-Intervention Left Hip Internal Rotation, degrees	% Change in Range of Motion
1	26.4	44.8	69.7
2	35.1	42.5	21.1
3	36.4	39.2	7.7
4	32.7	38.7	18.3
5	27.0	43.2	60.0
6	17.6	23.4	32.9
7	29.1	24.1	-17.2
8	31.9	37.3	16.9
9	34.8	36.9	6.0
10	24.6	40.1	63.0

Analyses of Variance for Range of Motion

Three, one-way analysis of variance (ANOVA) with pairwise comparisons were used to define the relationship between pelvic position and shoulder range of motion (IR and TM) as well as the relationship between pelvic position and hip range of motion.

Shoulder Internal Rotation ANOVA

A one-way repeated measured ANOVA was conducted to evaluate the null hypothesis that there is no difference in right shoulder IR over time(N=10). The results of the ANOVA indicated no significant time effect, Wilks' Lambda=.236, F (1, 9)= 1.612, p >.05, n^2= 100. Thus, there is no significant evidence to reject the null hypothesis.

Table 5. Right Shoulder Internal Rotation Results

Baseline	Post-Intervention	*P* for ANOVA
34.4 ± 7.4	37.5 ± 10.1	.236

Shoulder Total Motion ANOVA

A one-way repeated measured ANOVA was conducted to evaluate the null hypothesis that there is no difference in right shoulder total motion over time(N=10). The results of the ANOVA indicated a significant time effect, Wilks' Lambda=.035, F (1, 9)= 11.586, p <.05, n^2= 100. Thus, there is significant evidence to reject the null hypothesis.

Table 5. Right Shoulder Total Motion Results

Baseline	Day 4	Day 5	Post-Intervention	*P* for ANOVA
109.9 ± 8.7	122.8 ± 10.5	124.6 ± 7.3	127.7 ± 9.0	.035

Hip Internal Rotation ANOVA

A one-way repeated measured ANOVA was conducted to evaluate the null hypothesis that there is no difference in left hip IR over time(N=10). The results of the ANOVA indicated a significant time effect, Wilks' Lambda=.01, F (1, 9)= 10.53, p <.05, n^2= 100. Thus, there is significant evidence to reject the null hypothesis.

Table 4. Left Hip Internal Rotation Results

Baseline	**Post-Intervention**	***P* for ANOVA**
29.6 ± 5.5	37.0 ± 7.1	.010

Three one-way ANOVAs were conducted to evaluate the null hypothesis that there is no difference between shoulder TM, shoulder IR, hip IR and hip positioning. The results of the ANOVAs indicated no significant differences (p>.05). Thus, there is significant evidence to accept the null hypothesis for all cases.

Chapter 4: Discussion

Shoulder Internal Rotation

Overhead athletes, specifically baseball pitchers, are known to adapt in various ways to the unique stresses placed on their bodies.[1-4,10-16] However, these adaptations are highly individual, resulting in research being variable and conflicting at times. GIRD is one of the most conflicting adaptation in this realm of research, especially when discussing immediate and long-term (over the course of a season) effects. It is known to be an adaptation, but some researchers[2,11,13-15] argue that it may add extra stress to the anatomical structures, possibly increasing injury risk. Reinold, et al reported that there was a statistically significant reduction in dominant (throwing) shoulder IR and total range of motion immediately after throwing in professional pitchers. These reductions in range of motion were still significant up to 24 hours post-throwing.[41] However, Freehill et al found there was no significant decrease in shoulder IR over the course of a Major League Baseball season.[42] Similarly, McGraw et al found that there were no significant changes in range of motion over the season and any changes were not associated with workload (pitch count, velocity, etc.).[43] In addition, IR may be recovered post-pitching with intervention strategies.[43] In a population similar to our study, Dwelly et al, found no significant change in IR in collegiate baseball pitchers over the course of a competitive season.[44] Therefore, the current study may add to the conflicting research since no statistically significant change in IR was found; although 70% of participants had an overall increase in average IR during the brief intervention period.

Shoulder Total Motion

Participants in the current study had an average of 16.5% increase in right shoulder total motion. Of note is that participants gained a statistically significant amount of shoulder TM throughout the course of the study ($p<.05$). Shoulder TM is a recently and highly debated adaptation seen in the throwing shoulder. Although a deficit in IR was formerly seen as deleterious, Fortenbaugh, Fleisig, and Andrews found that a lack of external rotation or total motion may be more detrimental.[45] A lack of external or total motion would not allow the shoulder to reach proper motion at key points in throwing mechanics.[45] Furthermore, an increase in TM, as seen in the current study, may even act as a "protective mechanism" for the throwing shoulder.[15] While it is unknown if the gains observed in the current study yielded a protective effect, it is notable that participants gained a significant amount of shoulder TM, but not shoulder IR.

The mechanics of pitching may help to explain the increase in total motion. During the maximal cocking phase, the arm is placed in abduction and extreme external rotation.[46] This repetitive and extreme motion puts high amounts of stress on the anterior shoulder and surrounding structures. This stress often leads to a compromised anterior capsule coupled with laxity in the anterior ligaments.[46] Laxity in the anterior capsule would, hypothetically, lead to more external rotation. Opposite of the anterior shoulder, the posterior shoulder tightens and may become thicker.[46,47] This thickening of the posterior rotator cuff would limit IR while allowing for an increase in external rotation[47] and ultimately total motion.

While the current study only encompassed short-term changes, previous research has studied range of motion long-term. McGraw et al and Chan et al found that total motion significantly increases over a professional baseball season.[43,48] These increases may have been attributed to an intervention (stretching and exercise) that both groups researchers assigned to those pitchers who presented with significantly decreased range of motion at baseline testing. Although the current study only encompassed about 7 days in the very beginning of a season, the results follow the pattern of overall gain in range of motion. The pitchers in this study also voluntarily followed a standardized weighted ball program, to some extent. The program, which includes specific pre-pitching and post-pitching exercises and stretches, may also have contributed to the increase shoulder range of motion over the week.

Current and developing research[43,48] supports the notion that an increase in shoulder range of motion may be a protective adaptation rather than a detrimental change. During the offseason, these athletes may lose their respective, ideal range of motion. As a result, the first few weeks of the competitive season/pre-season would be a time frame for increased injury rates due to this less than ideal range of motion.[43] As time goes on, McGraw et al and Chan et al, show that the body may adapt to decrease the chance of injury by gaining total motion in the shoulder. These athletes follow a scheduled training program that includes different types of throwing that vary in intensity and repetitions. The differences in their types of throwing may cause an ebb and flow in range of motion.

Hip Internal Rotation

Hip rotational range of motion has been highly researched in baseball players to examine the effects of the kinetic chain on throwing. Early research shows that a decrease in hip rotation can be predictive of back and abdominal injuries in baseball players.[49] In our brief snapshot of data during the season, we found that there was a significant increase in left hip IR. This result conflicts with some current literature as Chan et al found that over a professional baseball season, pitchers significantly lost hip IR in both their lead and trail legs.[48] Additionally, Zeppieri, et al did not find any significant changes in hip rotation over a season.[25]

To try to explain why our pitchers may have increased hip IR in the week of data collection, it may be important to look at the pitching mechanics. It is seen that a right handed pitcher's left leg (their lead leg) will land in excessive IR every time they pitch.[25] Much like shoulder range of motion, these players may have lost the ideal hip rotation over the offseason. This may be even more true of the hip, since the idea of the kinetic chain and importance of the hips is research that is ongoing and continues to develop; therefore, pitchers may not work to increase or keep hip motion over their offseason time. As a result, the first few weeks of the season, such as in the current study, may be the time period that their body tries to play "catch up" and gain this range of motion.

Although research supports a loss of hip IR over the season, it is very limited. The point in time where these players may begin to lose their hip rotational range of motion is unknown. The current study supports that initially after a period of offseason they have the ability to gain hip IR, but we cannot say at what point they will start losing it, if at all. Research on the immediate effects of pitching on hip IR is limited or non-existent. Therefore, more research is warranted before conclusions can be made.

Left Anterior Inferior Chain (LAIC) Pattern

PRI® claims that the LAIC pattern can be observed in everyone due to daily repetitive patterns and the configuration of anatomy in the human body; however, there are no incidence or prevalence statistics available at this time. Therefore, any comparison of how many of the participants in this study presented with the pattern versus a normal population cannot be made. Nonetheless, given the PRI® claims, the lack of LAIC patterns observed during the intervention period was not expected. The participants in this study were elite athletes that were extremely in tune with their bodies and utilized strength and conditioning concepts every day. As a result, they may go in and out of this pattern at a different rate than an ordinary person. More research on the prevalence of this pattern in various populations is needed before direct comparisons can be made with confidence.

Chapter 5: Limitations and Future Research

There were multiple limitations to this study. First, the sample size was very small with the inclusion being only West Chester University baseball pitchers. Furthermore, the size and specificity of the sample with the number of variables limited the statistical analysis. As a result, the reliability of the results and the ability to generalize the results to other populations is hindered. Another limitation to the study was a lack of randomization and blinding. The principle investigator was the person to take the measurements, which increased the chance for bias. Lastly, the design being a pre-test/post-test design allowed for dropout, which excluded any participant that missed a day of intervention and measurements, further limiting the sample size.

Directions for Future Research

As is common in research, the current study raised more questions than did answers. The basis of this study was made on an assumption that the LAIC pattern could be found in almost everyone at any given time. However, as stated before, the exact prevalence of the pattern is currently unknown. Future research should aim to quantify the prevalence of the LAIC pattern in both average people as well as special populations, such as athletes.

Furthermore, the IR and TM debate continues to produce conflicting results. Future research is warranted before a conclusion can be made regarding which is more important in an overhead athlete. More specifically, the research should focus on showing which is more vital to maintain from an injury prevention standpoint.

In addition, since current research on the long-term changes in range of motion is limited future studies should use a longer intervention period. Ideally, this would be an entire season to show both short-term changes (day to day) and long-term changes (beginning to end). A future intervention period should also encompass the offseason in transition to a competitive season. This transition between these two different periods would help show the effects of prolonged rest during the offseason on shoulder range of motion.

Lastly, the current study is the first to connect hip range of motion to shoulder range of motion. Since no clear and conclusive evidence was found to show the relationship between the two, future research should intend to define this relationship.

Chapter 6: Conclusion

This study found that shoulder IR did not change significantly, but shoulder TM and hip IR did change significantly over the course of one week. The LAIC pattern was not observed as often as hypothesized. Ultimately, this study was conducted at the beginning of the competitive season after a prolonged period of no baseball related activities, which may have influenced the results.

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Appendix 1

WEST CHESTER UNIVERSITY

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West Chester, PA 19383 | 610-436-3557 | www.wcupa.edu

Protocol ID # 20191008F-R1

TO: Kaitlyn Williams, Mark Shires, Nicky Cattano, Noah Hebling
FROM: Melissa A. Reed, Ph.D.
Co-Chair, WCU Institutional Review Board (IRB)
DATE: 1/9/2020

Project Title: The Effect of Left Pelvic Repositioning on Contralateral Shoulder Total Range of Motion and Internal Rotation Deficit in Collegiate Baseball Pitchers
Date of Approval for Revision: 1/9/2020**
Please note that the original end date of your approved protocol still applies

☒**Expedited Approval**

This protocol has been approved under the new updated 45 CFR 46 common rule that went in to effect January 21, 2019. As a result, this project will not require continuing review. Any revisions to this protocol that are needed will require approval by the WCU IRB. Upon completion of the project, you are expected to submit appropriate closure documentation. Please see www.wcupa.edu/research/irb.aspx for more information.

Any adverse reaction by a research subject is to be reported immediately through the Office of Research and Sponsored Programs via email at irb@wcupa.edu.

Signature:

Melissa Reed

Co-Chair of WCU IRB

WCU Institutional Review Board (IRB)
IORG#: IORG0004242
IRB#: IRB00005030
FWA#: FWA00014155

West Chester University is a member of the State System of Higher Education

Appendix 2

Golden Rams
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September 16, 2019

To Whom It May Concern:
This note is to acknowledge that I am aware and approve the study being conducted by Kaitlyn Williams for her thesis that will include testing on baseball student-athletes.

Sincerely,

Jad Prachniak

Head Baseball Coach
West Chester University
JPrachniak@wcupa.edu

Appendix 3

Project Title: The Effect of Left Pelvic Repositioning on Contralateral Shoulder Total Range of Motion and Internal Rotation Deficit in Collegiate Baseball Pitchers

Investigator(s): Kaitlyn Williams; Alison Gardiner-Shires

Project Overview:

Participation in this research project is voluntary and is being done by Kaitlyn Williams as part of her Master's Thesis to investigate the effects of hip repositioning on shoulder and hip range of motion in collegiate baseball players. Your participation will take about 15-20 minutes to take health history questionnaire, range of motion measurements, arm pain questionnaire, hip repositioning technique. There is a minimal risk of mild discomfort during range of motion testing. There is possible increase in range of motion to you as the participant, and this research will help possible injury prevention strategy .

The research project is being done by Kaitlyn Williams as part of her Master's Thesis to investigate the effects of hip repositioning on shoulder and hip range of motion in collegiate baseball players. If you would like to take part, West Chester University requires that you agree and sign this consent form.

You may ask Kaitlyn Williams any questions to help you understand this study. If you don't want to be a part of this study, it won't affect any care you may receive from West Chester University. If you choose to be a part of this study, you have the right to change your mind and stop being a part of the study at any time.

1. **What is the purpose of this study?**
   - investigate the effects of hip repositioning on shoulder and hip range of motion in collegiate baseball players
2. **If you decide to be a part of this study, you will be asked to do the following:**
   - take health history questionnaire
   - range of motion measurements
   - arm pain questionnaire
   - hip repositioning technique
   - This study will take 15-20 minutes of your time.
3. **Are there any experimental medical treatments?**
   - No
4. **Is there any risk to me?**
   - Possible risks or sources of discomfort include: mild discomfort during range of motion testing
   - If you become upset and wish to speak with someone, you may speak with Kaitlyn Williams
   - If you experience discomfort, you have the right to withdraw at any time.
5. **Is there any benefit to me?**
   - Benefits to you may include: possible increase in range of motion
   - Other benefits may include: possible injury prevention strategy
6. **How will you protect my privacy?**

- The session will **not** be recorded.
- Your records will be private. Only Kaitlyn Williams, Alison Gardiner-Shires, and the IRB will have access to your name and responses.
- Your name will **not** be used in any reports.
- Records will be stored:
  - in a locked cabinet in Sturzebecker Health Sciences Center Room 222M, which will also be kept locked.
- Records will be destroyed Three Years After Study Completion

7. **Do I get paid to take part in this study?**
   - No
8. **Who do I contact in case of research related injury?**
   - For any questions with this study, contact:
     - **Primary Investigator:** Kaitlyn Williams at 717-880-5340 or kw822206@wcupa.edu
     - **Faculty Sponsor:** Alison Gardiner-Shires at 610-436-2515 or agardiner-shires@wcupa.edu
9. **What will you do with my Identifiable Information/Biospecimens?**
   - Not applicable.

For any questions about your rights in this research study, contact the ORSP at 610-436-3557.

I, _________________________________ (your name), have read this form and I understand the statements in this form. I know that if I am uncomfortable with this study, I can stop at any time. I know that it is not possible to know all possible risks in a study, and I think that reasonable safety measures have been taken to decrease any risk.

____

Subject/Participant Signature Date:________________

____

Witness Signature Date:________________

Appendix 4

Health History Questionnaire

Name: _________________________________ Age: _______

Height: _______ Weight: _______

# of years pitching competitively (travel team, high school, college, summer league team): _______

Dominant arm: Right Left

Pitching arm: Right Left

Please check if you have ever been **diagnosed** with the following injuries in the specific timetables (Please specify Right or Left)

Injury	Ever sustained	Within 2 years	Within 3-6 months
Rotator Cuff Tear			
Shoulder labral tear			
Hip labral tear			
Oblique strain			
Quadriceps strain			
Hamstring strain			
Adductor (Groin) strain			

Have you ever had surgery on your shoulder? ________

If yes, what kind of surgery and approximate date of surgery? _____________________________

Have you ever had surgery on your hip? ________

If yes, what kind of surgery and approximate date of surgery? _____________________________

Appendix 5

Appendix 6

Appendix 7

Baseline Measurement Data Sheet

Participant #: ______

Height: _______ Weight: _______

Left Hip Adduction Test (circle): Positive Negative

Right Hip Adduction Test (circle): Positive Negative

Range of Motion	**Left**	**Right**
Shoulder Internal Rotation		
Shoulder External Rotation		
Shoulder Total Range of Motion		
Hip Internal Rotation		XXXXXXX

Participant Data Sheet

Participant #: ________

Day: _______

Pre-Practice

Left Hip Adduction Test (circle): Positive Negative

Right Hip Adduction Test (circle): Positive Negative

Post-Practice

Left Hip Adduction Test (circle): Positive Negative

Right Hip Adduction Test (circle): Positive Negative

Range of Motion	Left	Right
Shoulder Internal Rotation		
Shoulder External Rotation		
Shoulder Total Range of Motion		
Hip Internal Rotation		XXXXXXX

Post-Intervention Measurement Data Sheet

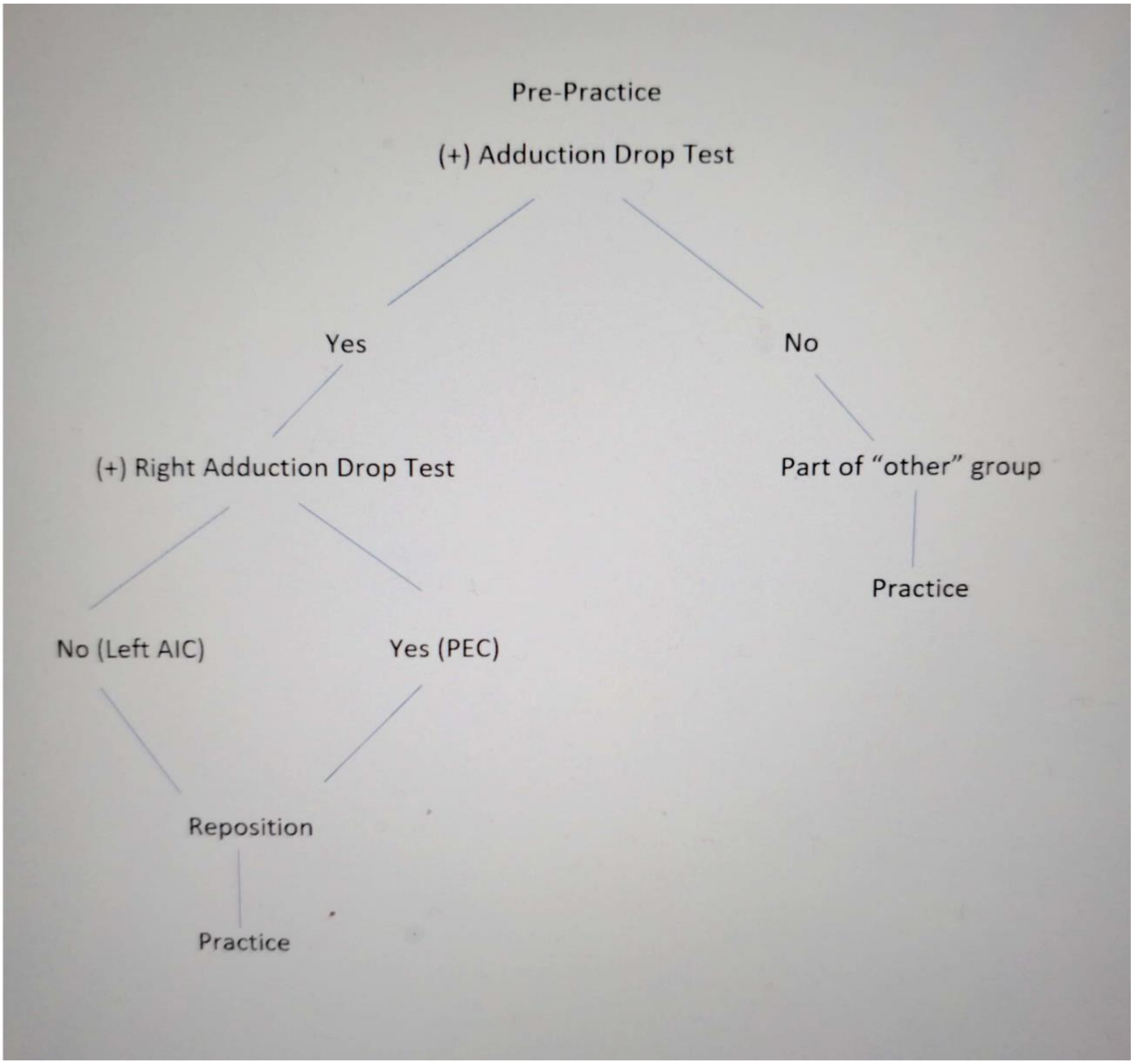
Participant #: ______

Left Hip Adduction Test (circle): Positive Negative

Right Hip Adduction Test (circle): Positive Negative

Range of Motion	Left	Right
Shoulder Internal Rotation		
Shoulder External Rotation		
Shoulder Total Range of Motion		
Hip Internal Rotation		XXXXXXX

Appendix 8



Pre-Practice
(+) Adduction Drop Test
Yes
No
(+) Right Adduction Drop Test
Part of "other" group
Practice
No (Left AIC)
Yes (PEC)
Reposition
Practice