Analysis of Glenohumeral Range of Motion in Division I Collegiate Softball and Baseball Athletes

by

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A majority of overhead throwing research and literature specifically addresses range of motion in baseball pitchers but does not include information pertaining to baseball position players. In addition, there is an overall lack of literature regarding range of motion analysis in softball athletes. The baseball pitching motion varies from the overhead throw position players in both softball and baseball use and therefore, warrants a separate conversation. This study aims to evaluate bilateral glenohumeral internal and external rotation and horizontal adduction range of motion measurements in softball and baseball players of various positions and identify if any display glenohumeral internal rotation deficit (GIRD) or posterior shoulder tightness (PST). Both GIRD and PST have been identified as common adaptations to the throwing shoulder as well as risk factors for shoulder injury. In this sample, dominant arm internal rotation was statistically significant when compared between baseball and softball players (p=0.013) and was the only statistically significant similar range of motion. The proportion of external rotation insufficiency (ERI) was the most notable in both baseball and softball players at 88.2% and 74.1%, respectively. While there were low numbers of GIRD and PST for both groups, the similarity in ERI alone warrants further research in softball players glenohumeral range of motion profile. It also suggests both baseball and softball players would benefit from clinical intervention prior to being diagnosed with GIRD or PST.

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1.0 Introduction

Softball is a rapidly growing sport in popularity and participation. The 2017-2018 High School Athletics Participation Survey showed 367,861 girls play softball while 20,316 women were participating at the collegiate level at a NCAA sanctioned institution.[1] Softball's male counterpart is baseball, which is often referred to "America's pastime" and current participation numbers reflect such. In the same study referenced above, 487,097 young athletes were recorded as participants in high school while 35,460 individuals participated at the collegiate level in a Division I, II, or III institution.[1] Sheer participation numbers warrant sports medicine research to provide a deep understanding of the sports which may help to prevent injury and better care for the athletes participating in their respective sports. An aspect of both sports that separates these athletes from all others is the overhead throw.

The overhead throw is a well-studied motion within sports medicine. Many factors can affect this motion just as this motion can have many effects on the human body. It is widely accepted that repetitive overhead throwing can lead to musculoskeletal adaptions to the upper extremity, especially in the glenohumeral joint. However, the musculoskeletal adaptations are debated as protective or pathologic. Glenohumeral internal rotation deficit (GIRD) and posterior shoulder tightness (PST) are among two of the common injury risks studied in overhead throwing athletes. The research involving GIRD and PST has been extensive in baseball players, specifically pitchers, but is lacking in softball players. With the similarities in the throwing motion of non-pitching softball and baseball players, injury risks affecting the upper extremity may well be present and similar in both sports.

1.1 Clinically Relevant Anatomy

This paper describes procedures on range of motion measurement data collection for the shoulder. An understanding of the shoulder anatomy will provide a background on the musculoskeletal structures involved in the data collection. Furthermore, it may allow the reader a better understanding of structures involved in glenohumeral internal rotation deficit and posterior shoulder tightness

1.1.1 Glenohumeral Bony Anatomy

The shoulder is a complex joint allowing for tremendous mobility. The glenohumeral joint within the complex will be the focus of this paper for its role in the motions necessary to throw overhead, and its involvement in GIRD and PST. The synovial ball-and-socket joint is comprised of three bones: the humerus, the scapula, and the clavicle. The glenoid cavity and acromion process arise from the scapula to form articulations with the humerus and clavicle, respectively. The glenoid cavity commonly rests in a neutral or anteverted position. This allows for a full articulation with the humeral head that is anteverted during maturation.

In the overhead thrower's shoulder, the glenoid cavity can be retroverted, and, more commonly, the humeral head can show signs of retrotorsion. Glenoid retroversion (GRV) and humeral retrotorsion (HRT) are currently seen as a normal, non-pathologic adaptations of the dominant arm in overhead throwers.[6] GRV is when the glenoid cavity is angles backwards as opposed to its more commonly neutral or slightly forward angle. HRT is the backwards rotation of the humerus, most prominently seen at the humeral head at the articulation with the glenoid cavity.

During maturation, the humeral head rotates forward, causing it to be anteverted from its relative retroverted position at birth. Repetitive overhead throwing during maturation can stress the epiphysis of the humerus and cause bony changes not allowing for normal antetorsion of the humerus. Over time, this leads to a relative retrotorsion of the humerus of the dominant arm when bilaterally compared thus allowing for an external rotation gain and internal rotation deficit. It has been observed in a study of 32 professional baseball pitchers that HRT and GRV are in a 2:1 ratio dubbed as the 'thrower's ratio' which suggests both adaptations likely occur simultaneously.[34] Similar studies have shown this adaption in adolescents and collegiate-aged athletes.[6] Evaluating and measuring the effects of these bony adaptations are outside of the scope of this paper, but it should be noted they can affect shoulder range of motion in addition to musculotendinous structures.

1.1.2 Glenohumeral Soft Tissue Anatomy

There are many musculotendinous structures involved in overhead throwing. The posterior glenohumeral joint is stabilized by the noncontractile articular capsule and, partially, by the inferior glenohumeral ligament. Contractile tissues like the infraspinatus and teres minor, both external rotators of the humerus, provide stability for the humerus articulating with the glenoid cavity. The infraspinatus originates from the infraspinous fossa and inserts on the greater tuberosity of the humeral head. The teres minor also inserts at the greater tuberosity but originates from the upper first third of the lateral border of the scapula. The posterior deltoid may also play a part in posterior shoulder stabilization since its posterior fibers originate on the spine of the scapula and move at a downward angle to insert on the deltoid tuberosity of the humerus. The subscapularis is the main internal rotator of the glenohumeral joint; it originates from the subscapular fossa and inserts onto the lesser tubercle of the humerus.

Anteriorly, the pectoralis major uses upper and lower fibers to horizontally adduct the humerus. The pectoralis major upper fibers originate from the anterior surface of the sternal ½ of the clavicle and insert onto the crest of the humerus' greater tubercle. The lower fibers, which supply the largest portion of the pec. major, originates from the sternum and cartilages of the first 6-7 ribs and inserts on greater tubercle of the humerus.

All the musculoskeletal structures discussed, in addition to others not highlighted, act to properly stabilize the shoulder. The rotator cuff, comprised of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles, act as stabilizers for the humeral head in the glenoid fossa while other muscles, like the latissimus dorsi, biceps brachii, and pectoralis major, along with the rotator cuff, act on the humerus to generate movement at the glenohumeral joint. Whenever one of these structures are affected, it can cause a cascade of issues because of their involvement in the overhead throwing motion. Overhead throwing is accomplished through the motions of horizontal abduction, external rotation, horizontal adduction, and internal rotation in addition to subsequent movements at the elbow and scapulothoracic joints. Due to the intricacies of these motions happening congruently, inefficiency of one muscle could cause the entire system to be disrupted. Normal glenohumeral motion for overhead throwers varies from the general population and has been well described in the literature.

It has been noted that overhead throwing athletes can expect a gain in external rotation and decreased internal rotation though the amount that is considered non-pathologic is debated. It is most common in repetitive overhead throwing for the posterior shoulder musculature or ligamentous structures to become tight. This tightness can decrease an individual's ability to horizontally adduct the glenohumeral joint as well as impede internal rotation. Repetitive throwing can cause microtrauma to the posterior shoulder causing the ligaments to become more rigid and allow for less mobility.[8] Currently, there is no clear delineation between bony, musculotendinous, or ligamentous structures causing PST. All structures must be accounted for when considering PST. To account for all structures, a variety of assessment tools must be used. Ultrasonography is common tool used to measure posterior cuff thickness as well as glenoid retroversion and humeral torsion which affect PST. This is outside of the scope of this study but is a direction for future research.

1.2 Range of Motion in Softball and Baseball Athletes

When discussing the overhead athlete population, it is necessary to understand the anatomy and the many adaptations that can occur. While musculoskeletal adaptations to sport are common and sometimes necessary for individual athletes' sport performance optimization, some adaptations can increase the risk of injury. Overhead athletes and the overhead throwing motion will be discussed in this section.

The current literature on overhead throwing athletes is mostly focused on baseball, namely baseball pitchers. Schilling, Mallace, and Elazzazi conducted a study in 2019 which included a comprehensive literature review of studies that recorded shoulder range of motion values for either baseball or softball players at the youth, collegiate, or professional level.[22] They commented that an overwhelming amount of the data available focused on baseball players and the collegiate level which conversely identified a gap in range of motion literature available on all softball players and non-pitching position players in baseball.

Shoulder range of motion in overhead throwing athletes is a common focus of sports medicine research and incredibly important to properly care for the overhead athlete. The body can adapt to the repetitive overhead throwing motion over time leading to changes in range of motion, mostly at the shoulder. It is paramount to understand what adaptations are normal and what are pathologic to guide treatment. Many studies have described normal range of motion values for the dominant arm of baseball pitchers.[6, 7, 10, 21, 22, 25, 27-29] Although there is range of motion data available for softball players, it is commonly focused on pitchers[18, 32] or adolescent athletes[24-26].

Some studies discuss range of motion in softball players, but they are not without limitations. Schilling, Mallace, and Elazzazi collected range of motion data on Division III collegiate softball and baseball players. The investigators did not measure any glenohumeral range of motion other than external and internal rotation.[22] They found no statistically significant differences between the dominant arm of softball and baseball players for internal rotation, external rotation, and total rotational motion (TRM). However, the number of softball players were less than half (n=24) of the baseball players' subject pool (n=50). Despite "test of homogeneity of variance indicated no significant difference between their group variances,"[22] this doesn't account for pitchers typically making up a large portion of baseball rosters. Although the results would be comparable, future studies should account for the number of pitchers included in the group samples as the throwing mechanisms for pitching in both baseball and softball differ completely from the overhead throw position players use which in turn completely alters the glenohumeral range of motion. Schilling et al. also included shoulder range of motion values on 50 baseball and 24 softball players in NCAA Division III level. Higher IR, which subsequently led to less GIRD, and

TRM values were seen in the throwing arm of softball players(IR = 65.9º±10.9º and TRM = 162.6º±11.9º) when compared to baseball players (IR = 54.1º±10.9º and TRM = 148.2º±11.6º).

Hibberd, Oyama, Tatman and Myers investigated dominant limb range of motion adaptations in collegiate softball and baseball position players and controls with no previous history of athletic overhead activity.[7] The variables assessed were humeral retrotorsion (HRT), glenohumeral internal rotation deficit (GIRD), external rotation gain (ERG), and total rotational motion (TRM). The study found softball players (ERG=1.0º±7.4º) demonstrated a statistically significant ($P = 0.002$) gain in external rotation compared to female controls (ERG= -6.4º±9.8º) but showed no significant differences in TRM, internal rotation, or humeral retrotorsion (HRT). There was no difference between baseball players and male controls in ERG which may be explained by understanding external rotation insufficiency as a pathologic adaptation to overhead throwing. Though there is some argument, much like the argument surrounding GIRD, external rotation insufficiency (ERI) has predominantly been seen as pathologic. Wilk et al. noted in a study of 296 professional baseball pitchers that a ERI in the throwing arm were 2.2 times more likely to be placed on the injured roster for shoulder injury.[33]The gain in external rotation most overhead throwers acquire overtime is seen as a normal, non-pathologic adaption to throwing, therefore, the lack of this gain in external rotation is seen as pathologic. Unlike Schilling et. al., Hibberd and colleagues excluded pitchers from both sports in this study. This makes the results for softball and baseball players more comparable to each other since their throwing mechanics are similar and differ from both softball and baseball pitching.

Hellem et al. also conducted a review of literature focused on range of motion at the shoulder in overhead athletes but delved into the origins of the range of motion differences instead of range of motion values.[6] The authors discussed bony and soft tissue adaptions at the shoulder and what is referred to as normal motion/adaptation versus a pathologic adaptation. The bony anatomy can respond to repetitive stress from overhead throwing in humeral retrotorsion (HRT) and/or glenoid retroversion (GRV). They found that in as young as 8 years old, baseball players may begin to display bilateral difference in HRT. However, the bilateral differences in HRT were comparable to varying levels and age groups within baseball and therefore, can be considered a normal adaptation within the shoulder.[6] Hibberd et al. noted HRT differed between the dominant and non-dominant arm in baseball players from 0°-29° with the throwing arm showing greater HRT while control groups showed no difference bilaterally.[7] This supports the concept that HRT is an adaptation to participation in overhead throwing activity.

1.3 Epidemiology of upper Extremity Injuries in Softball and Baseball

Upper extremity injury rates (e.g. type II superior labrum anterior to posterior [SLAP], rotator cuff and biceps strains, shoulder impingements, etc.)[23] have been documented in both high school and collegiate softball players and they are similar to their baseball counterparts. In a study of baseball adolescent (13-18 years) athletes, Shanley et al. found labral/internal impingement had the highest rate of occurrence in the cohort with ulnar collateral ligaments and rotator cuff and biceps strains all tied for second.[23] College softball players typically experience a higher total number of injuries than their high school counterparts, but both age groups have a similar spread of injuries occurring during competition and practices as well as similar injury locations.[30] Wasserman et al. found the shoulder/clavicle injury incidence rate per 1,000 athlete-exposures in collegiate softball practices was 0.42 in a 95% CI while the competition injury incidence rate was 0.31 with the same confidence interval.[30] The shoulder/clavicle was the second most commonly injured location for a collegiate softball player.[30] The upper extremity in collegiate softball players was also found to be the second most commonly injured major body part during games and practices by Marshall, Hamstra-Wright, Dick, Grove, and Agel.[15] Musculotendinous strains were the most commonly reported shoulder injury in both practices and games for collegiate softball players. Arguably, most muscular strains are preventable when considering overall joint health and modifiable parameters like frequency and/or intensity of load placed on the body.

It is theorized that common adaptations like glenohumeral internal rotation deficit (GIRD) and posterior shoulder tightness (PST) affect the overhead thrower's shoulder. Both PST and GIRD have been identified as injury risk factors in overhead athletes, but not clearly defined as existing specifically in softball players. PST and GIRD can be identified through range of motion measurements which is what this study aims to do.

1.4 Glenohumeral Internal Rotation Deficit

Internal and external rotation are two motions occurring at the glenohumeral joint that are imperative for throwing. A lack of internal rotation at the shoulder when compared bilaterally is known as glenohumeral internal rotational deficit (GIRD). While most currently available literature agrees on what GIRD is, many authors vary on the cutoff value loss to diagnose an individual with GIRD. There is also much debate about if GIRD is a protective mechanism or if a pathologic adaptation.

Johnson, Fullmer, Nielsen, Johnson, and Moorman stated a minimum of 18° loss of IR is needed to qualify an individual to have GIRD.[9] These authors conducted a meta-analysis that encompassed nine total articles with quantitative measurements pertaining to glenohumeral range of motion. They found 13.8° of internal rotation to be the average deficit of all injured throwers regardless of age. In contrast, Hellem et al. stated a cut-off of 13° internal rotation deficit for younger throwers is more appropriate than a 20° value for non-adolescent throwers. The 18.0° threshold for GIRD was established in 2012 at The Throwing Summit which was a year after the article Hellem et al. cited as their primary reference for establishing 20.0° as the threshold for GIRD was published.

Some studies have not linked GIRD to future injury unless it is coupled with total rotation motion (TRM) difference greater than or equal to 5° between the throwing and non-throwing arm.[10] Kevern, Beecher, and Rao stated if the loss in internal rotation is equal to the gain in external rotation, it is considered physiologic; an osseous change resulting in a protective mechanism. If the loss in IR exceeds gain in ER, this is considered pathologic; likely, soft tissue changes and more closely linked to injury.[11]

External rotation gain (ERG), demonstrated in baseball players, is an adaptation seen in the dominant (throwing arm) shoulder. ERG is defined as an increase of 5.0º or greater in the throwing arm when compared bilaterally; the inverse, a lack of 5.0º or less of external rotation in the throwing arm, is true for external rotation insufficiency (ERI).[14] A lack of ERG, or external rotation insufficiency (ERI), may increase the risk of shoulder injury.[33] ERG is an alteration that is considered normal in the baseball player's shoulder range of motion profile and has even been linked to greater degrees of humeral torsion.[7] This is of particular interest as some studies have shown a link between humeral torsion and ERG in addition to IR deficit and upper extremity injury in baseball players.[20]

Manske, Wilk, Davies, Ellenbecker, and Reinold attempted to settle the protective or pathologic debate by developing subcategories of GIRD definitions. In anatomical GIRD, an individual may have an IR deficit of 18°-20° with equal TRM bilaterally, while pathologic GIRD will have the same IR deficit with a greater than 5° TRM loss when bilaterally compared.[14] They reported a 2.5 times greater risk for a baseball pitcher to sustain a shoulder injury if the TRM of the throwing arm is not within 5° of the non-throwing arm. However, Johnson et al. completed a meta-analysis and noted a significant overlap between non-injured and injured groups in internal rotation deficits. This implied a lower threshold like 13.8º would be more beneficial for all age groups when determining when to intervene for the sake of injury prevention.[9] While internal rotation deficits of ≥ 13.8º are lower than the debated pathologic and/or non-pathologic ≥ 18.0º, it could still prove useful in intervention strategies to mitigate risk.

In some literature, it is still debated if GIRD is a normal or pathologic adaptation in the overhead thrower.[9, 14] A clear, concise definition within the sports medicine research community would aid in further understanding the etiology of GIRD.

A study completed by West, Scarborough, Mcinnis and Oh showed no differences in rotational motion at the glenohumeral joint when compared bilaterally in softball windmill pitchers.[32] However, they noted this was only seen in their cohort and was not consistent with other literature. A study by Oliver et. al. indirectly showed this to be true. Although the sample size of softball pitchers was not large enough to compare to softball position players, the study showed no bilateral differences in internal rotation in pitchers while statistically significant differences of IR were noted in position players.[19] Conversely, Werner, et al. have different findings. In their cohort of youth softball pitchers, they noted gains in ER and deficits in IR consistent with GIRD.[31]

While studies on GIRD in softball players exist, they only include pitchers. The windmill pitch is fundamentally opposite from the overhead throw, as the ball is released underhand in pitching. Linking normative values for pitchers to position players is inadequate and therefore presents a missing link in understanding the range of motion in softball players.

GIRD is debated as pathologic or non-pathologic, but when accompanied with TRM deficits, it may be more strongly predictive of overhead injury.[2] Together, internal and external rotation provide total rotational motion (TRM). A bilateral difference of ≤ 5.0° in TRM is shows a positive trend towards upper extremity injury.[10, 21, 25] Keller and colleagues completed a meta-analysis that encompassed 17 articles discussing shoulder range of motion and injury in overhead throwing athletes. Overall, a loss of TRM in the throwing arm when compared to the contralateral side, shows an increased risk of shoulder injury (2.5x) and elbow injury (2.4x) in overhead athletes.[10] However, this meta-analysis included studies with tennis and handball athletes, so results may differ if only baseball and softball athletes are investigated. It was noted in a study of 119 professional baseball pitchers that a 10° or greater loss of TRM lead to a 2.5 times higher risk of injury.[33] GIRD was specifically linked to a greater risk of ulnar collateral ligament (UCL) injury in a study examining baseball players who had undergone UCL repair.[4] GIRD has been proven as an injury risk in baseball pitchers and baseball position players. Since non-pitching softball and baseball players have a similar throwing motion, softball players could be experiencing similar injury rates and causes. GIRD has also been noted in softball players as an injury risk factor; a prospective cohort study completed by Shanley and colleagues revealed a loss of IR greater than 25° in the dominant arm put the upper extremity at four times a greater risk for injury when compared with subjects who had less than 25° of IR loss.[25]

Another strong predictive injury risk factor in the baseball pitcher's shoulder is posterior shoulder tightness (PST) which is characterized by a loss of 15° or greater in horizontal adduction when compared bilaterally.[6] PST has most frequently been linked to internal impingement.[16] PST has also been proven to show a significant correlation with IR deficits[13, 17] and therefore, may pose the same injury risks as GIRD.

1.5 Posterior Shoulder Tightness

Posterior shoulder tightness (PST), defined as a lack of 15° in horizontal adduction between the dominant and non-dominant arms,[6] can lead to a loss in horizontal adduction, internal rotation, and a gain in external rotation. Due to the connection between PST and IR loss and ER gain, PST has been linked to GIRD in previous studies.[8, 28] There are different views on why the posterior shoulder becomes tight and whether it is a protective mechanism or possible risk factor for injury.

Some studies have shown the dominant throwing arm has a thickening of the posterior shoulder capsule when compared bilaterally.[8, 21] Kevern et al. noted the repetitive stress in overhead throwing that can lead to pathologic GIRD can also cause microtrauma to the posterior capsule. This microtrauma can result in a thickening of the posterior capsule which has been linked to decreases in internal rotation.[8] Kevern et al. also noted surgical patients with GIRD had a contracted and thickened posterior-inferior band of the inferior glenohumeral ligament. However, thickening of the posterior capsule does not completely encompass all the musculoskeletal structures that could be involved in PST.

Decreased horizontal adduction or PST has been noted as an injury risk factor in overhead throwers. Hellem and colleagues also noted increased posterior capsule thickness has shown correlations with glenohumeral internal rotation deficits. Most authors agree that loss of motion in the shoulder when compared bilaterally is strongly correlated with development of shoulder and elbow injury or pain.[13, 18, 25] Shanley, et al. were able to specifically correlate shoulder range of motion deficits to injury in high-school aged softball pitchers.[25] The authors observed 27 shoulder and elbow injuries over a single season, and all players displayed significant decreases in horizontal adduction in the dominant arm. All injured baseball players (n=18) also demonstrated total rotational motion loss in the dominant arm when compared with their uninjured counterparts.

Shanley et al. completed another study in 2015 using adolescent baseball athletes as her subject population. The prospective cohort study took pre-season measurements and notes in the adolescent group significant bilateral differences in HA (24.0±18.0°) when compared with all other groups. While they used the established cut-off of ≥ 15.0º of HA difference, this shows even lower cut-off values trend toward injury risk in males.

While there have been links between shoulder range of motion deficits and pain and/or injury in softball players, it has only been described in pitchers. Due to the similarities between the overhead throwing motion in baseball and softball position players, the lack in research on softball position players may be missing range of motion deficits and their possible link to injury.

1.6 Problem Statement

Current research in shoulder range of motion is predominantly focused on male athletes, namely baseball players, and most of the research using baseball players as subjects concentrates on pitchers. As previously discussed, the baseball and softball cannot be discussed synonymously in sports medicine research. The throwing motion differences within sports also warrant discussing position players separately from pitchers. Both baseball and softball need research tailored to the specifications of their respective sports.

The clinical implications of using baseball research as evidence for clinical practice in softball players are significant. If the same risk factors are not present between the sports, it could possibly lead to misdiagnosis and therefore, mistreatment of softball players and their injuries. This research would add to the body of literature of normative range of motion values for all positions within NCAA Division I softball players.

Since lower thresholds exist prior to reaching a GIRD or PST diagnosis, internal rotation deficit ≥ 13.8° and horizontal adduction ≥ 10.0° respectively, it is useful to use these values when assessing the glenohumeral range of motion profile. If only GIRD and/or PST are considered, many athletes who would benefit from clinical intervention would be missed. This research will possibly identify the presence of an internal rotation deficit, external rotation insufficiency, and horizontal adduction deficit that are known to trend toward injury risks in both baseball and softball players.

1.7 Study Purpose

The purpose of this study is to examine shoulder range of motion in collegiate level softball and baseball players and identify if glenohumeral internal rotation deficit and posterior shoulder tightness are present.

1.7.1 Specific Aims & Hypothesis

1.7.1.1 Specific Aim 1

To describe glenohumeral internal rotation, external rotation, and horizontal adduction in softball and baseball position players.

1.7.1.2 Hypothesis 1

Softball and baseball position players will demonstrate similar glenohumeral range of motion.

1.7.1.3 Specific Aim 2

To evaluate and compare softball and baseball position players for internal rotation deficit (≥ 13.8°), external rotation insufficiency (≥ 5.0°), total rotational motion gain (≥ 5.0°), and horizontal adduction deficit (≥ 10.0º).

1.7.1.4 Hypothesis 2

While this aim is primarily descriptive, comparable numbers may be seen between baseball and softball athletes which would indicate an internal rotation deficit, external rotation insufficiency, an increase in total rotational motion, and a decrease in horizontal adduction in the throwing arm when compared bilaterally.

1.7.1.5 Specific Aim 3

To evaluate the percentage of collegiate softball and baseball position players with GIRD (IR ≥ 20° difference when compared bilaterally).

1.7.1.6 Hypothesis 3

While this aim is primarily descriptive, we hope to see comparable numbers between baseball and softball athletes which would show GIRD in the throwing arm when compared bilaterally.

1.7.1.7 Specific Aim 4

To evaluate the percentage of collegiate softball and baseball position players with PST (HA $\geq 15°$ difference when compared bilaterally)

1.7.1.8 Hypothesis 4

While this aim is primarily descriptive, we hope to see comparable numbers between baseball and softball athletes which would show PST in the throwing arm when compared bilaterally.

1.7.2 Study Significance

Normative data for shoulder range of motion is lacking in Division 1 collegiate softball players across all positions and in position players, outside of pitchers, in baseball. This study will minimally provide data on shoulder rotational range of motion and horizontal adduction. It will also describe the presence of a potential risk factor for shoulder injury in overhead athletes. This could aid in establishing normative values in healthy softball and baseball position players as well as provide reliable guidelines for obtaining normative values.

2.0 Methods

2.1 Experimental Design

The University of Pittsburgh Injury Prevention Initiative (UPitt IPI) was an analytical, cross-sectional study that collected data on National Collegiate Athletic Association (NCAA) Division I baseball and softball players from 2012-2016. All data were collected by personnel who had educational backgrounds in sports medicine and demonstrated competency in testing procedures. The original variables assessed included shoulder range of motion measurements, shoulder strength measurements, postural assessments, and data from health a questionnaire to provide descriptive statistics.

The present study was a retrospective data analysis of baseball and softball players included in the UPitt IPI study that assessed range of motion variables in non-pitching position players within Division I collegiate athletics. The purpose of this study was to first, compare differences and similarities between position players in softball and baseball and secondly, identify if glenohumeral internal rotation deficit (GIRD) and/or posterior shoulder tightness (PST) exist in these populations.

2.1.1 Dependent Variables

The dependent variables were glenohumeral horizontal adduction, glenohumeral internal rotation, and glenohumeral external rotation range of motion measurements measured in degrees (°). The dependent variables were shoulder horizontal adduction, internal rotation, and external rotation range of motion measurements measured in degrees (°). Glenohumeral internal rotation deficit (≥ 20.0°), total rotational motion (≥ 5.0°), and posterior shoulder tightness (≥ 15.0º) were also be evaluated.

2.1.2 Independent Variables

The independent variables in this study were position within sport (baseball vs. softball position players).

2.1.3 Operational Definitions

Internal rotation deficit was a bilateral difference of ≥ 13.8° in the dominant shoulder. GIRD was considered pathologic and a bilateral difference of ≥ 20.0° of internal rotation in the dominant shoulder. External rotation gain (ERG) was a bilateral difference of ≥ 5.0° of external rotation in the dominant shoulder whereas external rotation insufficiency (ERI) is < 5.0°. ERG is considered a normal adaptation to overhead throwing, and ERI has been identified as an injury risk factor in overhead athletes. Posterior shoulder tightness (PST) was a bilateral difference of ≥ 15.0° of horizontal adduction in the dominant shoulder. Horizontal adduction deficit (HAD) was a bilateral difference of ≥ 10.0° in the dominant shoulder. Total rotational motion (TRM) is internal rotation + external rotation. TRM difference was the internal and external rotation of the dominant arm subtracted from the internal and external rotation of the non-dominant shoulder measured in degrees (°).

2.2 Subject Recruitment

Individuals were recruited from the National Collegiate Athletics Association's (NCAA) Division I softball and baseball teams from The University of Pittsburgh. Eligibility for the study was determined after reviewing inclusion and exclusion criteria. All testing was performed at The University of Pittsburgh in the Fitzgerald Fieldhouse athletic training room. Institutional Review Board approval was obtained initially for the IPI study.

2.3 Subject Characteristics

2.3.1 Inclusion Criteria

Each individual that participated in this study was active on their respective teams' roster at the University of Pittsburgh and medically cleared for full athletic participation at the time of data collection.

2.3.2 Exclusion Criteria

Individuals were excluded if they sustained an upper extremity injury within the past 4 weeks of data collection.

2.4 Power Analysis

For the University of Pittsburgh Injury Prevention Initiative, any student athlete at the university that volunteered to participate in the study and met inclusion and exclusion criteria were included. De-identified range of motion data in 27 softball and 17 baseball non-pitching position players were available for data analysis.

2.5 Instrumentation

2.5.1 Anthropometric Measurements

Height (cm) were measured using a stadiometer (Seca North America, East Hanover, MD). Body weight (kg) were measured using a weight scale (BOD POD Version 5.2.0, COSMED USA Inc., Chicago, IL).

2.5.2 Goniometer

The goniometer is widely accepted as the reliable and valid method of assessing range of motion. It is highly portable and inexpensive to acquire. At the shoulder, it has be proven to have high inter-rater and intra-rater reliability (ICC values 0.85-0.99) for quantifying rotation range of motion.[3] Goniometers have also been proven to be reliable in flexion and abduction[12] and in supine horizontal adduction range of motion measurements.[17]

2.6 Procedures

2.6.1 Range of Motion

Goniometer measurements were obtained for all ranges of motion using previously established protocols.[29] For all measurements, there were two examiners: one to produce the passive motion and one to measure and record the reading. Measurements were taken on an adjustable examination table to allow for examiner and subject comfort. The motions were completed three times and averaged for statistical analysis.

2.6.1.1 Glenohumeral Horizontal Adduction

Subjects were laying supine with the shoulder in 90° of abduction and elbow flexion. The examiner was on the test side to stabilize the scapula and passively horizontally adduct the arm until a strong end feel was noted. The fulcrum of the goniometer was over the acromioclavicular joint while the proximal arm is perpendicular to the floor. The moving arm was aligned with the humerus.

2.6.1.2 Glenohumeral Internal and External Rotation

Subjects laid supine with the scapula stabilized by the examination table. The shoulder was abducted to 90°, and the elbow was flexed to 90°. A towel was placed between the table and the elbow to keep the humeral head in a neutral position. The examiner stabilized the subject at the anterior shoulder of the arm shoulder being measured and move the subject by applying a force on the forearm, anteriorly and posteriorly for external and internal rotation, respectively, until a firm end feel was met.

2.7 Data Reduction

2.7.1 Range of Motion

For all range of motion measurements, three trials were conducted in one session and averaged for the mean score. Results were recorded in degrees (°) to the nearest $1/10^{th}$.

2.7.2 Glenohumeral Injury Risk Factors

Glenohumeral Internal Rotation Deficit (GIRD) affects the dominant arm therefore, the dominant shoulder internal rotation was subtracted from the non-dominant shoulder internal rotation. In the same respect, posterior shoulder tightness (PST), was measured by subtracting dominant shoulder horizontal adduction from non-dominant shoulder horizontal adduction. Total rotational motion (TRM) is internal rotation added to external rotation. Similar to GIRD and PST, the difference in TRM was found by subtracting dominant TRM from non-dominant TRM.

2.8 Statistical Analysis

Descriptive statistics (mean, standard deviation, median, inter-quartile range and proportion, as appropriate) were calculated for all dependent variables, separately for softball and baseball players. Data were tested for normality using the Shapiro-Wilk test. Continuous variables were compared between groups using independent samples *t* tests or Mann Whitney *U* tests, as appropriate. Proportions were compared between groups using Fisher's exact tests. Statistical significance was set a priori alpha = 0.05, 2 sided. Data analysis was conducted using SPSS, Version 26 (IBM Inc., Armonk, NY.)

3.0 Results

3.1 Demographics

The original data set from the University of Pittsburgh Injury Prevention Initiative study included both baseball and softball players of all positions (n=72). When pitchers were accounted for and excluded, 44 subjects were identified for analysis, 27 softball and 17 baseball players.

Table 1 lists descriptive data for age, height, and weight for athletes included in the study.

The weight of baseball position players was higher than the weight of softball position players, $p < 0.001$. The baseball position players also demonstrated greater height than the softball players, $p < 0.001$. There was no significant difference in age between the softball and baseball players, $p = 0.160$.

Table 1 Descriptive Statistics for All Position Players, Softball Players, and Baseball Players

	Softball and Baseball Position Players (n=44)			Softball Position Players (n=27)			Baseball Position Players (n=17)		
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum
Age (years)	19.25 ± 1.26	18.00	22.00	19.04 ± 1.29	18.00	22.00	19.59 ± 1.18	18.00	21.00
Height (cm)	172.77 ± 9.48	160.02	193.04	166.60 ± 4.90	160.02	177.80	182.58 ± 5.02*	172.72	193.04
Weight (kg)	76.37 ± 13.10	54.43	101.97	68.58 ± 8.64	54.43	93.80	88.73 ± 8.65*	76.33	101.97

Statistical significance set at a priori $\alpha = 0.05$

3.2 Range of Motion Descriptive Statistics

3.2.1 Results for Glenohumeral ROM in Softball and Baseball Position Players

The first aim of this study was to describe glenohumeral internal rotation, external rotation, and horizontal adduction in softball and baseball position players. Table 2 provides descriptive statistics on non-dominant and dominant shoulder range of motion in softball and baseball position players. Between the two groups, the only statistically significant difference was found in dominant arm internal rotation, $p = 0.013$.

Table 2 Glenohumeral Range of Motion Descriptive Statistics for Baseball and Softball Position Players

	Baseball n=17			Softball n=27			
	Mean ± SD	Median	IQR	Mean ± SD	Median	IQR	**Group Comparison *p*-value**
Non-Dominant Internal Rotation	58.12 ± 8.81	59.33	53.67, 62.83	62.01 ± 8.51	59.00	55.67, 69.33	**0.152**
Non-Dominant External Rotation	93.31 ± 13.62	98.33	85.50, 102.33	100.57 ± 11.76	100.33	93.00, 106.33	**0.189+**
Non-Dominant Horizontal Adduction	109.78 ± 6.49	109.67	106.83, 114.83	108.46 ± 7.96	108.33	103.67, 114.67	**0.567**
Dominant Internal Rotation	47.57 ± 9.78	46.67	42.17, 54.17	54.91 ± 8.75	56.33	48.67, 61.00	**0.013***
Dominant External Rotation	100.80 ± 13.06	102.00	91.00, 111.33	105.31 ± 11.24	107.33	98.00, 113.00	**0.231**
Dominant Horizontal Adduction	105.94 ± 8.20	106.00	101.17, 110.67	108.85± 8.96	108.67	104.67, 112.33	**0.285**

+ non-parametric test used

Statistical significance set at a priori $\alpha = 0.05$

3.2.2 Results for Internal Rotation Deficit, External Rotation Insufficiency, Total Rotational Motion Difference, and Horizontal Adduction Deficit

The second aim of this study was to evaluate and compare softball and baseball non-pitching position players for internal rotation deficit (≥ 13.8°), external rotation insufficiency (≤

5.0°), total rotational motion difference (≥ 5.0°), horizontal adduction deficit (≥ 10.0º). Table 3 shows the percentages of baseball and softball players with each range of motion difference.

Table 3 Results of IR Deficit, ERI, and TRM Difference Analysis

	Baseball	Softball	Fischer's Exact Test *p*-value
Internal Rotation Deficit	7/17 = 41.2%	5/27 = 18.5%	0.164
External Rotation Insufficiency	15/17 = 88.2%	20/27 = 74.1%	0.445
Total Rotational Motion Difference	8/17 = 47.1%	11/27 = 40.7%	0.76

Baseball players (n=7) and softball players (n=5), 41.2% and 18.5% respectively, showed signs of an internal rotation deficit ≥ 13.8° (p=0.164) for a collective average deficit of 20.64º. Both baseball and softball position players displayed high percentages of external rotation insufficiency but the proportion of players with external rotation insufficiency was not statistically different between the two groups (p=0.445). Baseball players (n=15) and softball players (n=20), 88.2% and 74.1% respectively, had ≤ 5.0° of external rotation in their dominant throwing arm. Total rotational motion difference bilaterally was present in 40.7% of softball players and 47.1% of baseball players, p=0.76. No reported results were statistically significant.

3.2.3 Results for GIRD and PST

Specific Aim 3 was to identify the percentage of collegiate softball and baseball position players with GIRD (IR ≥ 20° difference when compared bilaterally) while Specific Aim 4 was to identify the percentage of PST (HA ≥ 15° difference when compared bilaterally). There were no statistically significant findings within the softball and baseball cohorts for GIRD (p=0.065) or for PST (p=0.371) although some athletes displayed the pathologic ROM deficits. Only one out of 27 softball players displayed signs of GIRD while four out of 17 baseball position players showed signs of GIRD. These findings for softball players were similar in PST as only two out of 27 displayed signs of PST. No baseball position players showed signs of PST.

Table 4 Results of GIRD and PST Analysis for Baseball and Softball Players

	Baseball	Softball	Fischer's Exact Test *p*-value
GIRD	4/17 = 23.5%	1/27 = 3.7%	0.065
PST	0/17 = 0.0%	2/27 = 7.4%	0.515

4.0 Discussion

4.1 Review of All Specific Aims & Hypothesis

The aim of this study was to evaluate, describe, and compare dominant arm shoulder range of motion characteristics in softball and baseball non-pitching, position players. Internal and external rotation and horizontal adduction were the motions examined. These values provide information on internal rotation deficiency, external rotation insufficiency, total rotational motion, and horizontal adduction deficiency which can further add to the body of literature surrounding glenohumeral internal rotation deficit (GIRD) and posterior shoulder tightness (PST). GIRD and PST are commonly known upper extremity injury risk factors in overhead throwing athletes. Injuries like labral pathologies, tendonitis, and ulnar collateral ligament tears are significant time loss injuries for overhead throwing athletes and can sometimes be detrimental to the athlete's career. A better understanding of the range of motion characteristics adding into these risk factors of serious injury would possibly be useful in early recognition, prevention, and treatment of upper extremity injury.

4.2 Glenohumeral Range of Motion Characteristics

Through evaluating softball and baseball non-pitching position players, it was hypothesized there would be similarities in the observed range of motion values due to similarities of the throwing motion in both sports. The numbers in Table 2 above show similarities in range of motion between softball and baseball position players, with only dominant arm internal rotation being statistically significant. This could be because the most intense aspect of throwing across both sports would be the deceleration phase in throwing. The teres minor and infraspinatus of the rotator cuff, in addition to other posterior shoulder musculature, are contracting eccentrically during deceleration.[5] Eccentric contractions are known to cause greater muscle breakdown opposed to their concentric counterpart. This breakdown may cause microtrauma to the musculature resulting in tightness. Tightness in the posterior musculature may prevent full rotational motion in the shoulder, specifically in internal rotation. While the throwing motions are similar in the position players, the differences in throwing distances between not only positions within sport (e.g. a second baseman throwing to a first baseman versus a left fielder throwing to a first baseman) but also between sports (e.g. the distance between bases in softball is 60 ft. versus the distance between bases in baseball is 90 ft.). The ball weight and size vary between sport with softball's ball being larger and heavier than baseball's which could completely alter the kinetics when throwing.

The results showed 41.2% of baseball players and 18.5% of softball players displayed signs of internal rotation deficits ≥ 13.8° which can be seen in appendix A.1. Internal rotation deficits as low as 13.8° have been linked to shoulder injury[9] albeit less observed than GIRD which is a deficit of 20.0°. If we simply observe internal rotation with a focus on pathologic GIRD, many throwing athletes who may benefit from clinical intervention to prevent injury would be overlooked and could potentially develop pathologic GIRD. Oliver et. al. demonstrated this by examining a softball team (n=49) and establishing clinically significant side-to-side differences at as low as 6.8°.[19]

Interestingly, external rotation insufficiency (ERI) (< 5.0° of external rotation gain in the throwing shoulder when compared bilaterally) was observed in both softball and baseball position players though it was also not considered statistically significant. As shown in appendix A.2, data analysis revealed 88.2% of baseball players displayed signs of ERI while 74.1% of softball players fell into the same category. ERI has previously been discussed as an injury risk factor in overhead athletes, but literature detailing its occurrence in softball players is lacking. With ERI's common trend towards injury risk, it is interesting to note the proportion of the softball players in this sample with ERI. The counterpart to ERI is, external rotation gain (ERG), and is more widely discussed as it is thought to be a normal, non-pathologic glenohumeral joint adaptation to repetitive overhead throwing. When an athlete has ERI, they are lacking the necessary ERG for overhead throwing. However, ERG data in softball players is also lacking. Schilling et. al. showed 10 out of 24 Division III collegiate softball players possessed a greater than five degree gain in external rotation, but it was not statistically significant and included softball pitchers.[22] ERG was not examined within this study, but an interesting direction for future research could be an investigation into both ERI and ERG in softball players.

As shown in A.3, no softball or baseball players had a horizontal adduction deficit of 10.0 or more without also being in the PST category. This could potentially be explained by the small sample size. It could also warrant further distinction between GIRD and PST. While they have been linked, GIRD and PST may be more different than similar since the internal rotation deficit proportion was much high comparatively to the horizontal adduction deficit in both baseball and softball. Again, the sample size of both sports was relatively small, so further research is warranted with a larger sample size.

It was also noted in the range of motion characteristics of the subjects that total rotational motion difference bilaterally was present in 40.7% of softball players and 47.1% of baseball players which is shown in A.4. In Schilling's et. al. study on Division III softball (n=24) and baseball players (n=50), they found similar results in TRM deficits in that they had no statistically significant findings but similar percentages.[22] While the present study didn't identify statistical significance of the proportions of IR deficit, ERI, or TRM between baseball and softball players, the figures display the similarities in proportions which further illustrates the similarities in the range of motion profile within these groups of overhead throwers.

4.3 Glenohumeral Internal Rotation Deficit

Glenohumeral internal rotation deficit (GIRD) is a known risk factor for upper extremity injuries like labral tears, biceps tendonitis, and ulnar collateral ligament sprains in overhead throwers. We aimed to evaluate and describe the presence of GIRD within the subject group available. A subject was identified as having GIRD if their dominant arm had a loss of 20° or more of internal rotation when compared bilaterally to their non-dominant arm. In the present study, four baseball players and one softball player presented with GIRD. The results of this study were not statistically significant which is in contrast to previous work by Hibberd et. al. who found significant differences between baseball and softball position players in GIRD.[7] Entire studies, like Wyland et. al. studied bony adaptations leading to GIRD in professional baseball pitchers[34], are completely dedicated to the injury risk factor in this specific subset. Although this study may not be the first to examine GIRD in Division I collegiate softball players, it is one of a few. There have been studies involving both softball and baseball players in the same cohort at the youth level, but those results aren’t generalizable to the collegiate age group due to physical differences resulting from maturation. Some studies have also focused on either softball or baseball in separate cohorts but rarely exclude pitchers and therefore, the data is skewed because the throwing motions between pitchers and position players in their respective sport vary greatly, especially in softball.

4.4 Posterior Shoulder Tightness

A deficit in horizontal adduction when compared bilaterally is known as posterior shoulder tightness (PST). PST is an injury risk factor in overhead throwers. This risk factor has been closely linked to GIRD since a deficit in internal rotation can be linked to tightness in certain muscles that also affect the amount of horizontal abduction in the glenohumeral joint. The current study aimed to identify and describe the presence of PST in the softball and baseball player subject pool.

In this study, PST was defined as a lack of 15° or more of horizontal adduction in the dominant arm when compared to the non-dominant arm. No baseball players presented with PST while only two of 27 softball players met the criteria. PST is commonly found in baseball players which makes these results inconsistent with previous research. The lack of male subjects presenting with PST could possibly be due to a small sample size (n=17) of baseball players. Pitchers commonly account for a large portion of baseball rosters and a majority of research in overhead throwing athletes. Since we excluded pitchers while only completely the study at one university, the sample size of baseball position players was relatively small. There is also a possibility the athletes were already involved in preventative programs to address range of motion deficits.

While the softball players did present with two cases of PST, the findings were not statistically significant. The existing body of literature addressing the presence of PST in softball is small and inconclusive currently.

4.5 Limitations and Future Research

The main limitation of this study arose from a small sample size of both softball and baseball athletes. A larger sample size may have been able to provide a better generalizability to the overhead throwing athlete population.

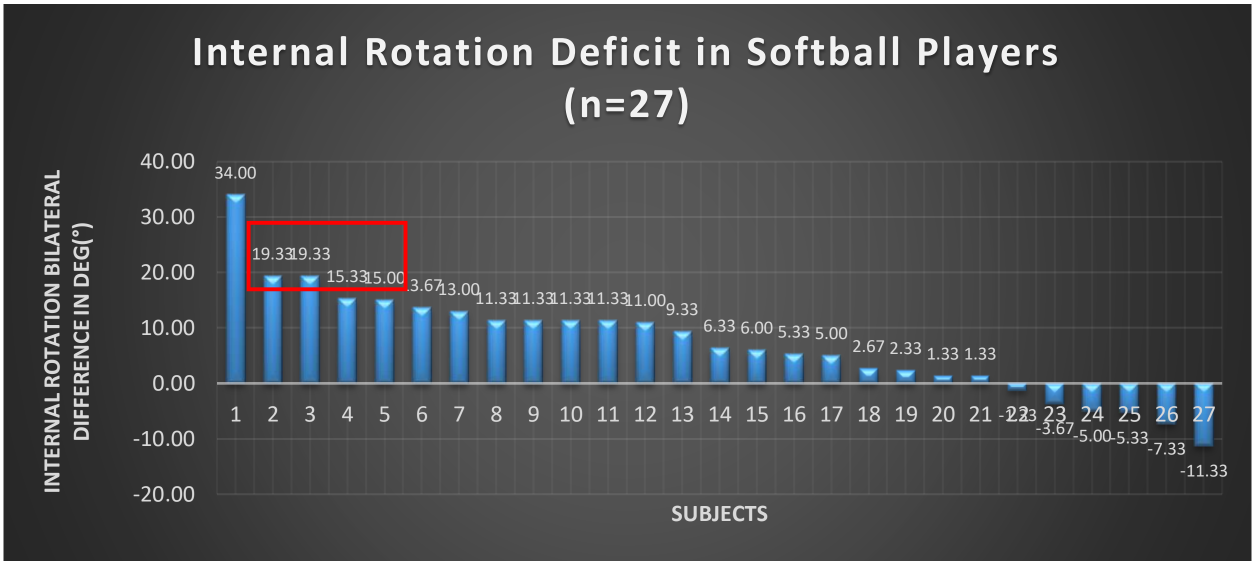
Future research should consider including larger sample sizes of both softball and baseball non-pitching players. This study identified softball players with external rotation insufficiency albeit a non-statistically significant amount. It is worthwhile for future research to identify if ERI is a commonality in softball players as it is a known injury risk factor in overhead athletes. ERI, along with other risk factors like GIRD and PST in addition to general ROM values of IR, ER, and HA could easily examined in a cross-sectional study of a large baseball and softball cohort. An interesting direction would be to complete a prospective study following a softball cohort from entry to exit in collegiate athletics. This would allow for a better understanding and documentation of practices, strength and conditioning sessions, and games. If the sports medicine team was well staffed and on board, ROM measurements could be taken upon entry to school, pre-season, and post-season each year along with injury documentation. This would allow for documentation of ROM changes associated with different seasons, training periods, and injuries.

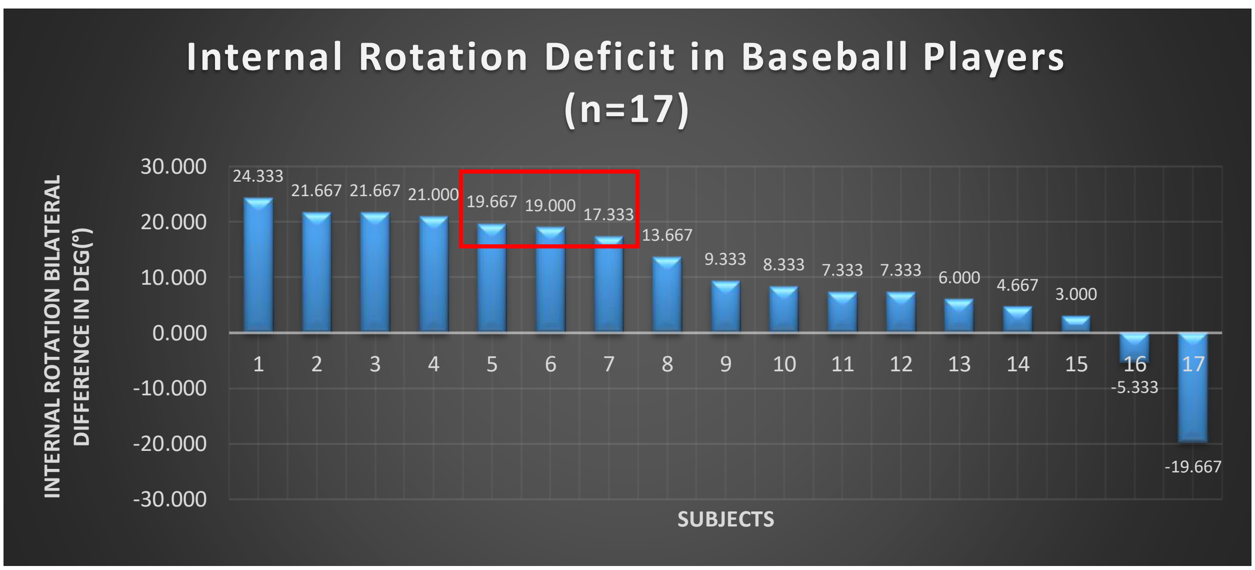
4.6 Conclusion

The results of this study show there is more work to be done to identify glenohumeral range of motion characteristics of position players in softball and baseball. The throwing motions of position players between sports are similar and though some studies demonstrate statistically significant differences in ROM[7], some equally demonstrate statistically significant similarities which can reasonably be expected due to the shared biomechanics of overhead throwing. This current study demonstrates statistically significant similarities in internal rotation between both softball and baseball but failed to provide significant results in any other ROM characteristic or in GIRD and PST. Future research should include larger sample sizes to ascertain statistically significant results in ROM characteristics and clarify normal values. Without viewing the lower threshold of internal rotation deficit $\geq 13.8°$ compared to GIRD $\geq 20.0°$, many athletes would not be considered at risk for possible injury or trending towards injury risk. It is also worthwhile to further investigate external rotation insufficiency and total rotational motion in baseball and softball players as these values, in addition to internal rotation insufficiency, are often overshadowed by GIRD and PST despite all values being important for understanding and caring for the overhead thrower's shoulder. Sports medicine research must also strongly consider the similarities of the overhead throwing motion between baseball and softball while still recognizing the stark differences between the sports. Further research into softball players and baseball position players is warranted in order for sports medicine clinicians to provide the best healthcare for optimal performance in these athletes.

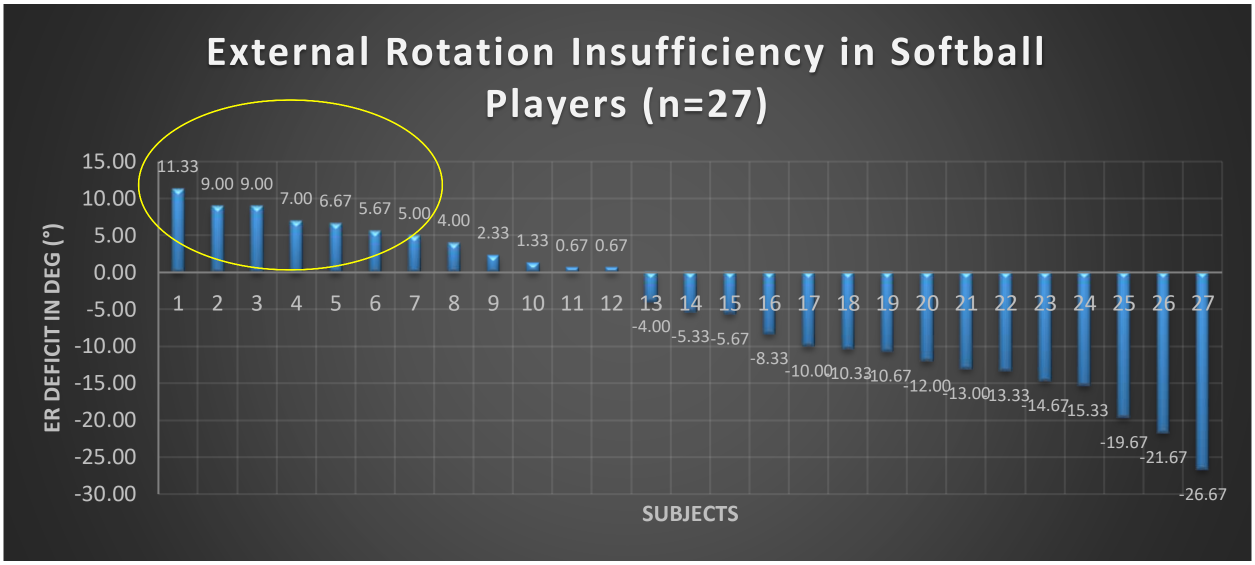
Appendix A Charts for Discussion

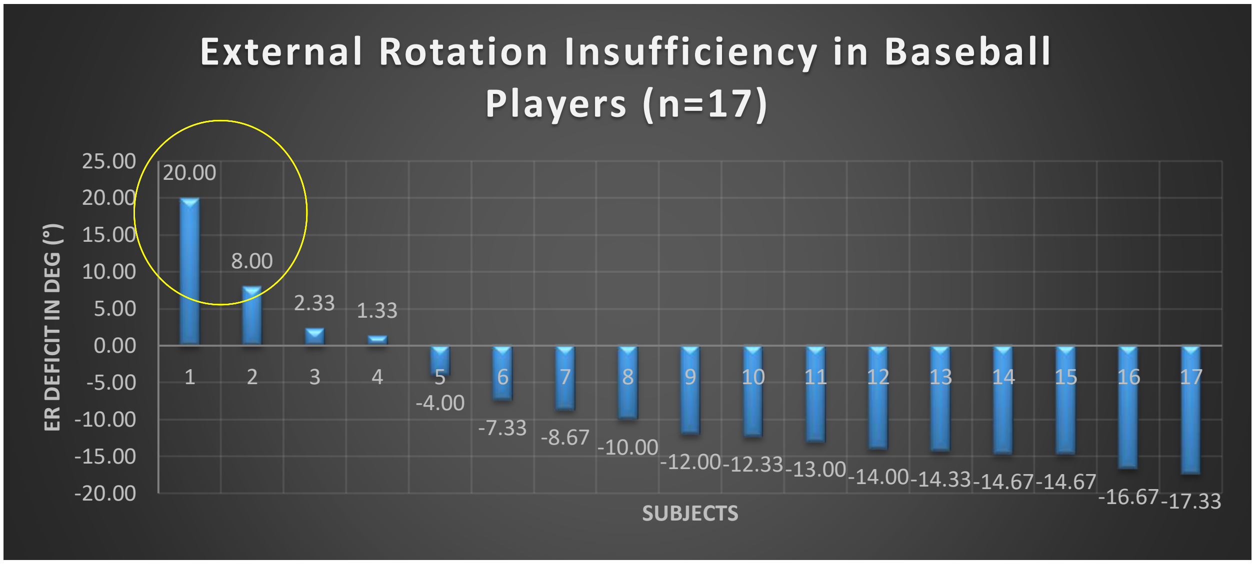
Appendix A.1 Internal Rotation Deficit in Softball and Baseball Players



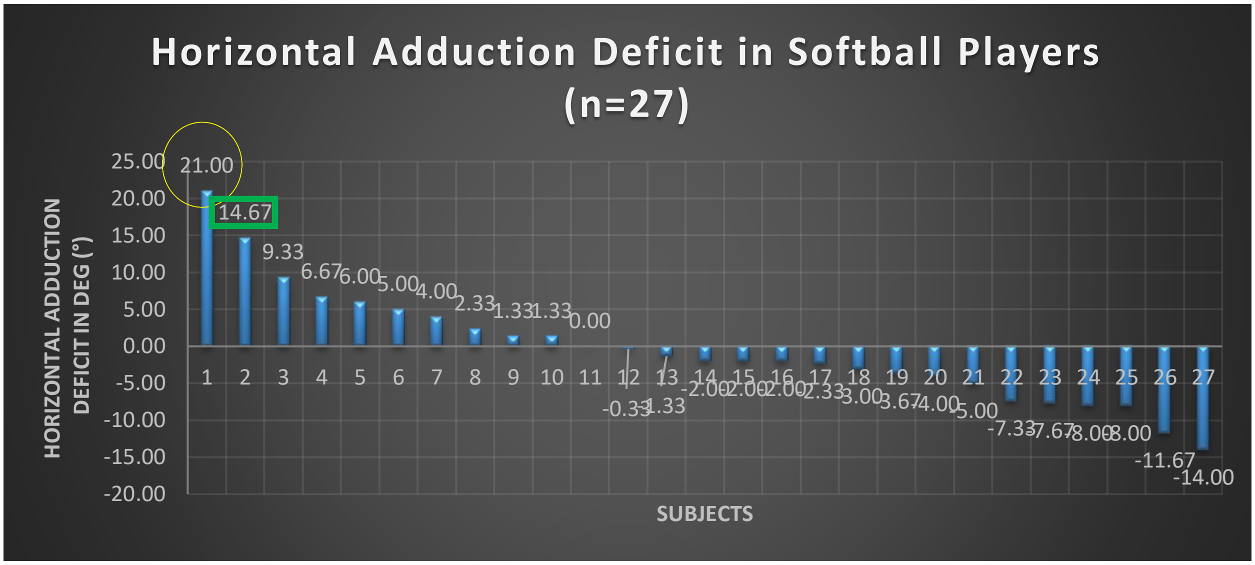


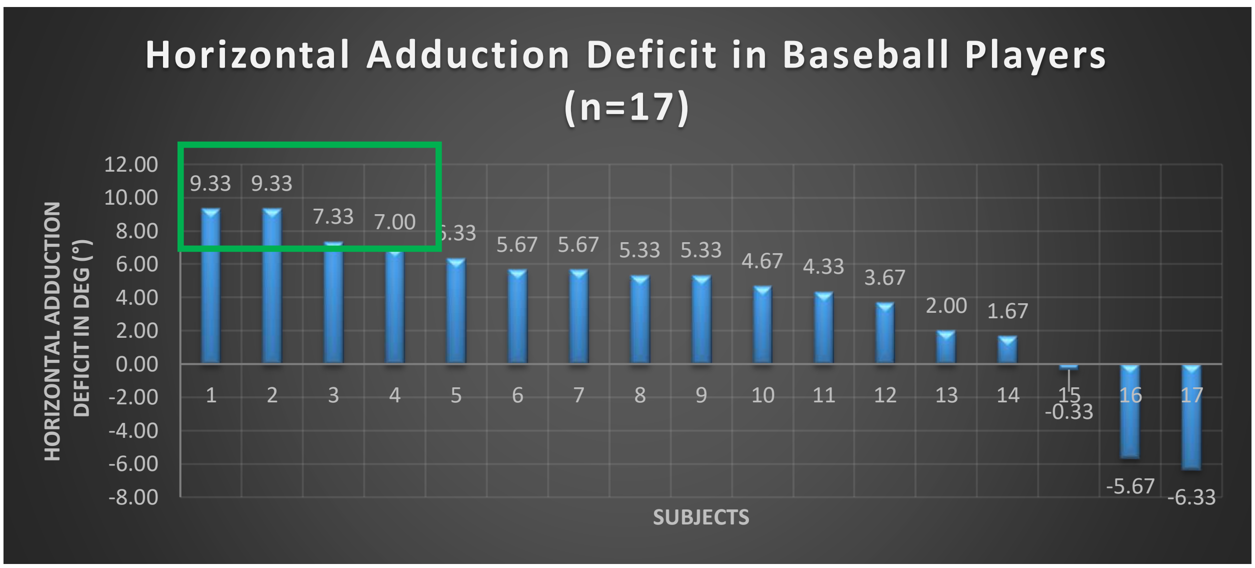
Appendix A.2 External Rotation Insufficiency in Softball and Baseball Players



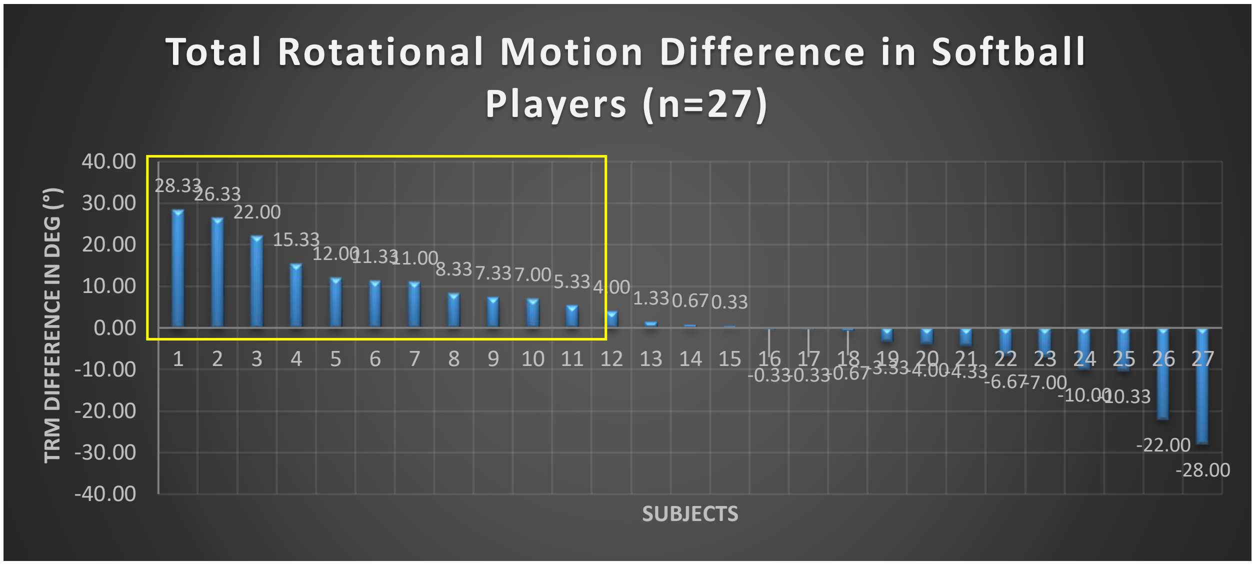


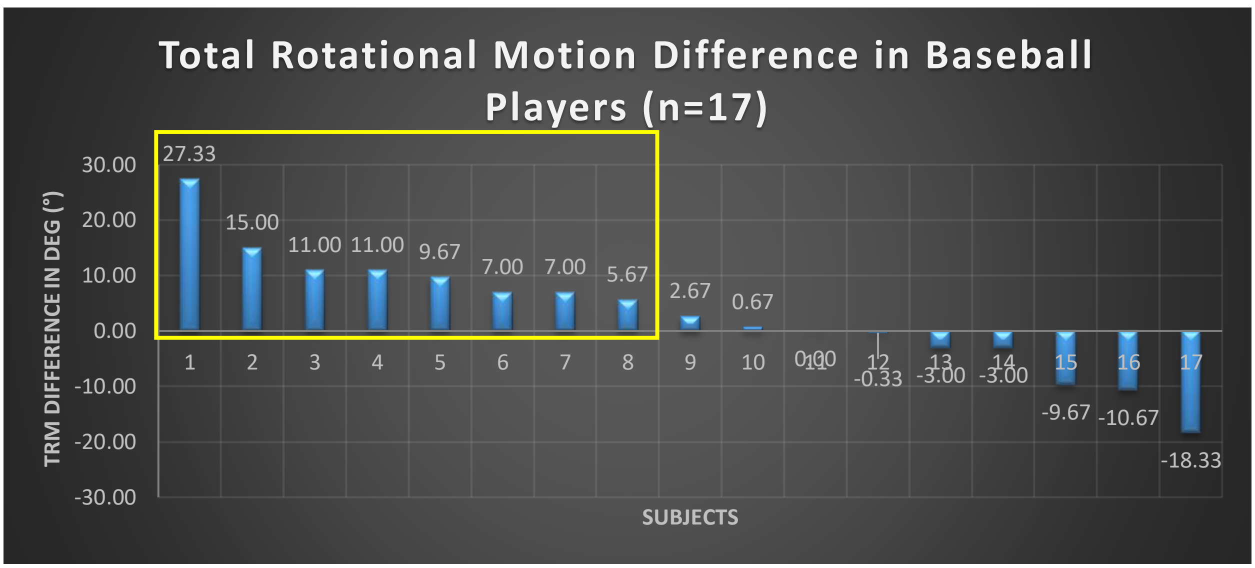
Appendix A.3 Horizontal Adduction Deficit in Softball and Baseball Players



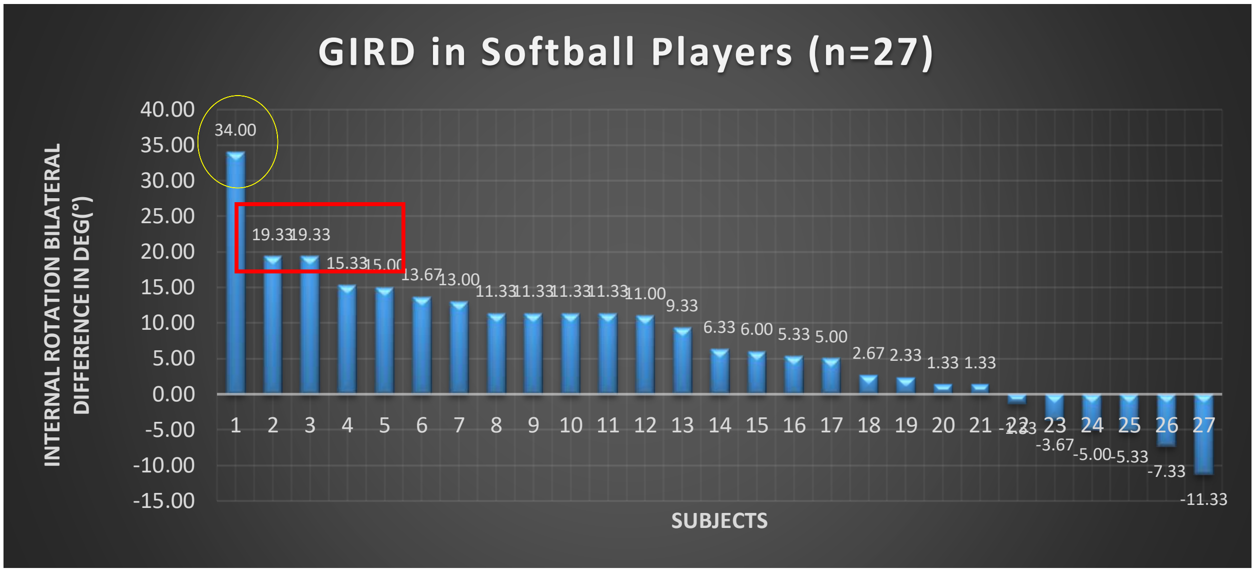


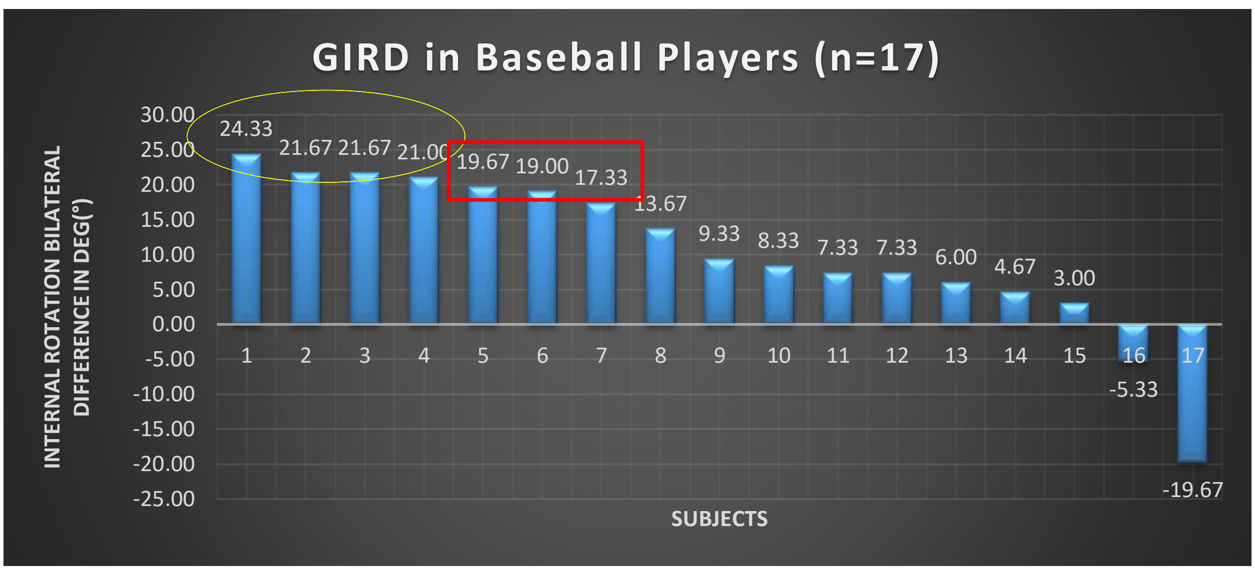
Appendix A.4 Total Rotational Motion Difference in Softball and Baseball Players



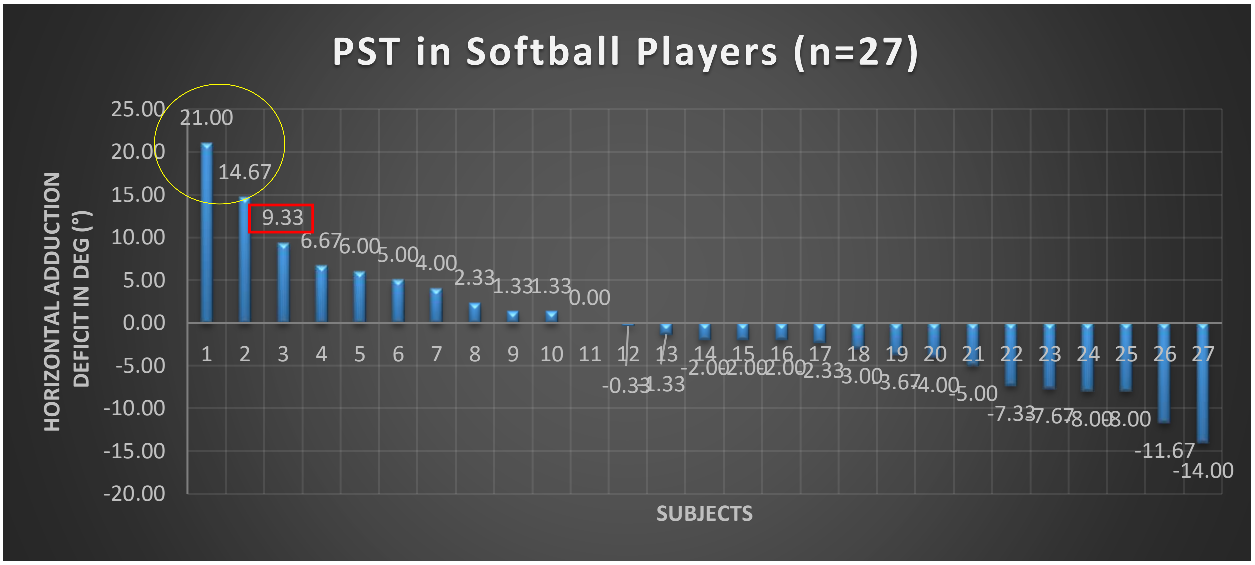


Appendix A.5 GIRD in Softball and Baseball Players





Appendix A.6 Posterior Shoulder Tightness in Softball and Baseball Players



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