Development of a Field Expedient Screening Tool for the Coach to Identify Musculoskeletal Risk Factors in Baseball Players

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DEVELOPMENT OF A FIELD EXPEDIENT SCREENING TOOL FOR THE COACH TO IDENTIFY MUSCULOSKELETAL RISK FACTORS IN BASEBALL PLAYERS

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Health Sciences at the University of Kentucky

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2021

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ABSTRACT OF DISSERTATION

DEVELOPMENT OF A FIELD EXPEDIENT SCREENING TOOL FOR THE COACH TO IDENTIFY MUSCULOSKELETAL RISK FACTORS IN BASEBALL PLAYERS

Identification of musculoskeletal (MSK) injury risk factors in baseball players can be challenging particularly for youth and high school coaches. Many baseball coaches lack a sports medicine and/or strength and conditioning staff to assist with injury prevention initiatives. Given the extensive responsibilities in managing the team and preparing the players for athletic competition, little time remains to focus on injury prevention and arm care programs. Furthermore, assessment, diagnosis, and management of MSK impairments is outside the scope of practice and expertise of baseball coaches. However, educating and empowering the coach to efficiently screen their players for potentially injury producing MSK impairments is more practicable. Therefore, the purpose of this dissertation was to develop a time efficient, feasible, field expedient screening tool which can be reliably administered by the coach and identify important MSK risk factors common in baseball.

To mitigate overuse arm injuries, baseball coaches implement arm care programs to target MSK injury risk factors by improving strength, dynamic stability, and range of motion (ROM) of muscules and joints. Historically, arm care exercise programs consisted of generalized upper body strengthening or targeted stretching to a particular muscle group; however, current usage and understanding of arm care exercise programs among baseball coaches is lacking. A nation-wide survey of 654 high school baseball coaches revealed that 1) 87.3% (n=571/654) of coaches surveyed are using arm care programs, 2) only 18.6% (n=106/571) of these programs are individualized based on the specific needs of the player, 3) older coaches with more coaching experience are more likely to design individualized arm care programs, 4) lack of benefit (41%, n=34/83) and limited staffing (31.3%, n=26/83) were the greatest barriers to implementing arm care programs, and 5) coaches demonstrate inconsistent knowledge of MSK risk factors and injury prevention.

Most coaches (57.3%, n=375/654) surveyed take responsibility for playing the largest role in preventing baseball injuries, however, proper resources and knowledge of MSK risk factors limits their effectiveness. Empowering the coach with a screening tool which can be performed in less than three minutes and requires no equipment is a reason-
able solution. The Arm Care Screen (ACS), modified from the principles of the Functional Movement Systems, includes three components scored as pass or fail to screen the rotational mobility of the shoulders, hips, and spine and dynamic balance. In a cohort of 31 baseball players, the ACS demonstrated substantial intra-rater reliability ($k=0.76$; 95% CI, 0.54-0.95) and excellent inter-rater reliability ($k=0.89$; 95% CI, 0.77-0.99) when performed by high school baseball coaches with minimal movement screening training.

Although movement screening is generally reliable, the discriminability of screening to discern MSK risk factors is unknown. In a cohort of 110 baseball players (youth, $n=30$, high school, $n=50$, and college, $n=30$), high sensitivity was observed on the reciprocal shoulder mobility (0.90; 95% CI, 0.82-0.95), 90/90 total body rotation (0.85; 95% CI, 0.77-0.91), and lower body diagonal reach (0.84; 95% CI, 0.76-0.90) screens of the ACS suggesting sufficient ability to identify MSK risk factors. The screen was able to discriminate between the impairment measures for all age levels except for thoracic spine rotation ROM. Shoulder, hip, and spine ROM and dynamic single leg balance measures were significantly lower in players who failed the corresponding ACS component except for shoulder and hip external rotation ROM.

The ACS is a feasible tool for baseball coaches to consider due to its simplistic scoring criteria, minimal staffing and equipment requirements, and its ability to detect MSK risk factors common in youth, high school, and college baseball players. Identification of MSK limitations is critical to addressing injury risk factors. Time efficient screening could allow coaches the opportunity to perform more frequent screenings and more closely monitor for development of risk factors throughout the season to potentially inform and thus refine arm care exercise programs.

KEYWORDS: Musculoskeletal risk factors, baseball, screening reliability and validity, arm care exercise program

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06/21/2021
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"Your work is going to fill a large part of your life, and the only way to be truly satisfied is to do what you believe is great work. And the only way to do great work is to love what you do. If you haven't found it yet, keep looking. Don't settle. As with all matters of the heart, you'll know when you find it."

-Steve Jobs

I dedicate this dissertation to my kids—Lilly and Andrew. I hope I’ve shown you to find your passion and use it to challenge the status quo in order to build a better tomorrow.
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CHAPTER 1. INTRODUCTION

1.1 Background

Baseball is one of the most commonly played sports in the United States with approximately 11.5 million athletes of all ages participating.\(^1\) An estimated six million of these participants are considered youth or adolescent athletes and are between the ages of 7-17 years old.\(^2\) Participation in high school baseball among male athletes continues to trend upward in the United States. As of the 2017-2018 season, 487,097 high school athletes were engaged in baseball, which is a noticeable increase from 470,600 participants twelve years ago during the 2005-2006 season.\(^3\) Unfortunately, as participation in high school baseball has increased over the last 10 years so have musculoskeletal injury rates, specifically injuries involving the shoulder and elbow.\(^4\) From 2005 to 2015 the incidence for shoulder or elbow related injuries in high school athletes has increased from 1.26 per 10,000 athletic exposures (AEs) to 1.39 per 10,000 AEs.\(^5\)

Musculoskeletal (MSK) injury in baseball players is a persistent and substantial sports medicine dilemma.\(^6\) For example, the results of a prospective longitudinal cohort of 298 youth baseball pitchers elucidated that over two seasons 58% of these athletes reported pain in the shoulder or elbow.\(^7\) Baseball related injury and impairment can have a significant long-term impact on physical health and quality of life among high school baseball players.\(^8\) Reduced physical function and well-being can manifest into chronic pain and joint stiffness and result in increased medical expenses throughout the life span.\(^9\) Compared to other throwing sports, baseball related injuries are more frequent and typically result in greater time loss from sport.\(^10,11\) Specifically, baseball pitchers have a greater rate of shoulder and elbow injuries compared to softball pitchers. Over the last
decade, the rate of elbow and shoulder injuries in softball pitchers were 0.41 per 10,000 AEs and 1.14 per 10,000 AEs, respectively. Injury rates for the elbow and shoulder in high school baseball pitchers were 0.86 per 10,000 AEs and 1.39 per 10,000 AEs, respectively. The majority of baseball related injuries happen during live game competition, involve the shoulder or elbow joints and occurs in pitchers more than position players. A significant number of baseball related injuries are overuse in nature and only result in three-seven days of time loss from competition. However, missing time from sport does not necessarily mean that the athlete is asymptomatic and free of injury risk factors. In a survey of 203 healthy baseball players aged 8-18 years, approximately 74% of pitchers reported pain with throwing and 23% reported injury histories consistent with overuse. Symptoms such as the presence of pain, fatigue, and overuse may become inappropriately overlooked and disregarded by the athlete or coach, potentially leading to a more severe injury. Injury epidemiological investigation from 2005-2006 to 2014-2015, found that 21% of injuries sustained in high school pitchers are more severe requiring greater than three weeks to return to sport. According to a prospective longitudinal study, 5% of youth pitchers sustained a serious injury within 10 years of play which resulted in either surgery or inability to continue with their baseball career.

The annual rates of ulnar collateral ligament (UCL) reconstruction surgeries have disproportionately risen in 15-19 year old pitchers in recent years. UCL reconstructions in high school age athletes are associated with an average annual incidence of 6.3 per 100,000 persons which is significantly greater than all other age demographics. Further...
thermore, the 15-19 years age cohort showed the greatest increase in UCL surgeries performed compared to any other age group with an annual growth rate of 9.84%\(^{21}\) and they occur most frequently during the first month of the season.\(^{12}\) A retrospective chart review conducted between the years of 2007 to 2011 indicated that high school aged baseball pitchers between the ages of 15-19 years accounted for 57% of all UCL reconstructions done in the United States during this time period.\(^{21}\) It is anticipated that the annual incidence of UCL surgeries in high school aged players will continue this disproportionate trend through the year 2025.\(^{22}\) Specifically, it is projected that the annual incidence for UCL surgeries in this age demographic could reach 14.6/100,000 people which is nearly two-fold greater than the next highest age demographic (20-24 years group).\(^{22}\)

The increasing incidence of injury in adolescent baseball players has not gone unnoticed. Researchers have spent the last two decades exploring the relationship between increased pitching volume and overuse upper extremity injuries.\(^{4,7,18,20}\) These associations have led researchers and sports medicine professionals to recommend guidelines to limit pitching volume.\(^{24}\) Current literature has focused on the understanding and compliance of established age specific pitching guidelines such as, the USA Baseball Medical and Safety Advisory Committee (USA-BMSAC) Pitch Smart guidelines, from the perspective of the parents,\(^{25}\) coaches,\(^{26}\) and athletes.\(^{27}\) The aforementioned guidelines focus on reducing the MSK stresses imposed on the shoulder and elbow joints by managing throwing volume and ensuring rest and recovery throughout the season. Whereas managing workload in adolescent baseball pitchers seems reasonable, there is uncertainty regarding the coaches’ knowledge level and compliance with these injury prevention guidelines.
Baseball players depend heavily on the expertise and direction of their coach. However, youth and high school baseball coaches are typically not experts in the field of sports medicine, nor have access to resources to develop injury prevention programs. Moreover, many states do not require prerequisite certification for high school coaches in basic knowledge of sport skills, coaching strategies, or mandating previous coaching experience.\textsuperscript{28} As a result, youth and high school baseball coaches have demonstrated a lack of knowledge and compliance specifically related to injury risk factors and adherence to pitching guidelines.\textsuperscript{26,29} Furthermore, youth coaches appear to be equally uninformed regarding adherence to safety guidelines. On average, only 43\% (n=41/95) of coaches were able to correctly answer questions pertaining to pitch count and rest periods.\textsuperscript{29}

Unfortunately, adolescent pitchers also lack adherence to pitching volume and safety standards. Despite established pitching guidelines, youth pitchers continue to engage in activities that increase their risk for injury. As many as 85\% (n=82/98) of baseball players are unaware of USA-BMSAC overhead throwing safety guidelines.\textsuperscript{27} In a survey of 754 pitchers age 9-18 years, 43.4\% reported pitching on consecutive days, 30.7\% pitched on multiple teams with overlapping seasons, and 19.0\% pitched multiple games per day.\textsuperscript{17} It appears that adolescent baseball players and their coaches must take a greater responsibility in monitoring pitching volume and workload throughout the season. However, pitch count tracking from competitive games is only representative of a portion of actual throwing volume. Typically, live game pitch counts are an underestimation of total throwing volume as 37.4\% of throws are associated with long tossing, bullpen sessions, warming up in between innings, and playing other positions.\textsuperscript{30} Moreover, managing pitching volume and workload does not account for all the potential factors associated
with sustaining a throwing related injury. Lazu et al, reported that pitching volume throughout the season explained only 50% of the relationship with onset of arm soreness in collegiate pitchers. In other words, 50% of the onset of arm soreness remains unexplained by pitching volume alone which suggests that other factors are contributing to development of overuse injury.

Baseball related injury could also be mitigated through better understanding of the physical contributions required of the MSK system to efficiently deliver a high-quality performance. The skill of pitching is complex and requires sequential linkage of multiple body regions through the kinetic chain to transfer energy from the lower extremity to the upper extremity. Toyoshima et al reported that approximately 47% of the pitching velocity was attributed to force development in the lower body. Furthermore, inefficiencies encountered throughout the kinetic chain results in compensatory strategies, energy leakage, and greater dependence on other joints to produce similar force for throwing. Specifically, development of mobility limitations and/or strength and stability imbalances alters the throwing motion and can result in increased stress on joints unable to handle the extreme forces. A disrupted kinetic chain coupled with increased pitching volume could potentially explain why injury rates have not declined and are projected to increase in over the next decade. Moreover, managing physical dysfunction and providing the kinetic chain with the opportunity to perform appropriately may actually increase the MSK tolerance for elevated pitch volume. Thus, high school coaches must be aware of the importance of monitoring for changes in MSK function in response to the increasing workloads throughout the course of the season.
Generally, baseball coaches and sports medicine professionals have recommended and utilized arm care exercise programs targeting strength and flexibility of the throwing arm to prevent injuries. The degree to which injury prevention programs are implemented depends largely on the knowledge and beliefs of the coach. A survey of 66 high school soccer and basketball coaches found that only 52% of coaches were aware that injury prevention programs were effective at reducing lower extremity injury rates. Moreover, only 21% of these coaches actually administered an injury prevention program for their teams. However, it is unclear if these beliefs regarding injury prevention programs are consistent among high school baseball coaches. Currently, the features of arm care exercise programs and how commonly they are implemented for baseball players at the high school level is unknown.

In additional to pitch counts and workload, several important MSK impairments and risk factors have been identified in the literature as contributors to overuse injury in overhead throwers. Lack of awareness of injury prevention strategies could hinder adoption of arm care exercise programs. Although coaches acknowledge the necessity of off-season arm care and strengthening programs, when surveyed only 13% (n=8/61) of coaches were able to correctly identify risk factors for overuse injuries. Thus, positive mindsets toward arm care exercises may not be sufficient enough to change behavior and result in implementation of meaningful programming. However, coaches may be more engaged to deliver effective injury prevention strategies if given more autonomy and responsibility. The multifactorial nature of athletic injury warrants consideration of the interaction of multiple risk factors that expands beyond pitch counts and workload.
Therefore, for a holistic injury prevention system an additional strategy may need to be utilized for prevention of baseball related injuries.

Medical and orthopedic evaluation performed by physicians and physical therapists have shown to be effective at identifying important MSK impairments that could lead to injury. However, it is unrealistic for most youth and high school programs to have access to medical and orthopedic personnel for their entire team throughout the season. This is problematic because the high demand nature of pitching can result in measurable changes in shoulder mobility, hip range of motion (ROM), and single leg balance over the course of the season. Specifically, MSK injury risk factors that were not present during the preseason may become detectable as the season progresses. A simplistic screening tool, which can be administered by the coach, to identify important MSK risk factors in their players could be useful to monitor for changes in physical function and/or development of risk factors. Empowering the coach with a simple method for evaluating MSK function is warranted for complete injury prevention programing. Youth baseball coaches have found success using techniques such as an injury risk checklist for identifying players at increased risk for injury. However, the information gained from the checklist was not used to educate or guide intervention to modify the risk factors and prevent injury. Regardless, coaches may find more success and better adherence with a field expedient tool that simplifies detection of major injury risk factors designed for the non-medical professional. Understanding when important MSK risk factors develop could inform a structured and targeted approach for arm care exercise programming prior to the injury event.
1.2 Problem

Many baseball coaches lack a sports medicine and/or strength and conditioning staff to assist with injury prevention initiatives. Given the extensive responsibilities in managing the team and preparing the players for athletic competition, little time remains to focus on injury prevention and arm care programs. Furthermore, assessment, diagnosis, and management of MSK impairments is understood to be outside of the scope of practice and expertise of high school coaches. As a result, coaches rely on group-based generalized injury prevention programs that have the potential but lack the effectiveness and efficiency that a more specific individualized program could provide.

Current best practice involves gaining information regarding MSK impairments and risk factors through pre-participation physical examinations (PPE). Although PPEs are effective at identifying potential MSK dysfunctions in athletes, PPEs require additional resources such as more staff, time, and equipment. Also, these resources are not always available to all coaches at all levels of play. It is difficult to replicate the information gained from the baseline testing of a PPE at multiple time points throughout the competitive season. Therefore, any risk factor that develops after the PPE, such as asymmetrical shoulder total range of motion, loss of glenohumeral internal rotation ROM, decreased hip ROM and strength, and poor balance, will go unnoticed and unmanaged which could potentially lead to injury and lost time from sport.

Additional staffing and resources to perform a physical examination at multiple time points are unrealistic expectations particularly for most youth or high school baseball programs. However, educating and empowering the coaches to efficiently screen
their players for the potentially injury producing MSK impairments throughout the season is much more obtainable. Thus, the development of a time efficient and field expedient screening tool to capture important MSK risk factors associated with baseball is a reasonable solution. Implementation of this screening procedure could better inform programming to improve current arm care programs for baseball players.

There are three unknowns to consider that this research proposal will address: 1) the implementation and features of arm care exercise programs as well as the injury prevention beliefs amongst high school baseball coaches is unknown. 2) a field expedient screening tool which can be reliably performed by high school baseball coaches does not currently exist, and 3) it is unknown if a proposed screening tool can discriminant between players with and without common MSK injury risk factors common in baseball.

1.3 Purpose and Aims

The goal of this proposal is to design a field expedient screening tool which can be implemented by the coach and identify common MSK risk factors found in baseball players. This instrument can empower youth, high school, and college level baseball coaches to obtain a more autonomous role in injury prevention and awareness which could better inform arm care exercise programing for their players.

Specific Aim 1: To investigate if high school baseball coaches are using arm care programs to promote shoulder and elbow health for their players. The primary objective was to determine if high school baseball coaches are implementing generalized group-based programs or individualized arm care based on the specific needs of the player. The secondary objective sought to investigate if the use of arm care programs is influenced by
coaches’ age, education, and experience level. Finally, this study explored potential barriers to arm care implementation and high school baseball coaches’ current awareness and beliefs associated with injury prevention.

**Hypotheses:** This aim will explore four hypotheses: 1) It was hypothesized that most surveyed high school coaches would design arm care programs using non-individualized group-based arm care exercise programs. 2) Older coaches with a higher education level will be more likely to implement individualized arm care exercises. 3) Limited time and staff will be the greatest barriers hindering arm care exercise implementation for high school coaches. 4) High school coaches will demonstrate limited knowledge of important injury risk factors in baseball players.

**Specific Aim 2:** To establish the intra-rater and inter-rater reliability of a novel arm care screening tool in high school baseball coaches. Additionally, we wish to explore if high school baseball coaches and physical therapists demonstrate similar scoring results on the Arm Care Screen (ACS).

**Hypotheses:** This aim will test two hypotheses: 1) It was hypothesized that the ACS will demonstrate no less than moderate intra-rater and inter-rater reliability with a Cohen’s kappa value >0.40 when administered by high school baseball coaches. 2) There will be no difference in ACS scoring results between high school baseball coaches with minimal experience screening movement and a physical therapist with multiple years of movement screening experience.

**Specific Aim 3:** Investigate the discriminant validity of the ACS to accurately identify the presence or absence of known MSK risk factors specific to baseball players which could lead to overuse injuries. The secondary purpose of this study was to determine if the ACS
can be utilized in youth, high school, and college level baseball players for identifying decreased ROM and balance limitations.

**Hypotheses:** This aim will evaluate two hypotheses: 1) It was hypothesized that poor performance on the ACS components would be highly sensitive at detecting the presence of at least one associated MSK risk factor. 2) It was hypothesized that youth, high school, and college level baseball players who failed the ACS components would have lower mean impairment measures compared to those who passed regardless of age.

### 1.4 Clinical Implications

Development of a screening tool consisting of fundamental movements which could be administered in less than three minutes with no equipment could be useful for baseball coaches without access to a sports medicine team. Barriers such as limited time, resources, and staff have been identified as common reasons for not pursuing injury prevention and arm care programming in youth and high school baseball. The value of the information gained from the screening tool would provide a way to identify the presence of important MSK risk factors and provide guidance for individualized preventative programming. This comprehensive approach could enhance the effectiveness and compliance of group-based arm care programs by focusing on the impairments which need intervention.

This screening approach also allows coaches to monitor for changes in physical movement quality throughout the season. Physical changes due to the development of muscle tightness or soreness as the season progresses could manifest into an injury risk factor. This model allows for coaches to design preventive exercises specific to the indi-
vidual athlete and adjust the arm care program according to changes that may occur during the season. This will allow the coach to best serve the needs of their team, reduce important MSK risk factors which could lead to injury, and provide the players with the best opportunity to optimize their athletic potential.

1.5 Operational Definitions

1. Arm Care Screen (ACS): a method consisting of three different movements for identifying the presence of MSK risk factors and/or impairments common in baseball players.

2. Arm Care Exercise Program: a program that consists of exercises to improve strength, ROM, and dynamic stability of muscles or joints directly or indirectly related to shoulder and elbow health in throwing athletes.

3. Adolescent Baseball Player: an individual in the 10-19 years age range who participates in the sport of baseball.

4. Youth Baseball Player: an individual in the 11-15 years age range who participates in sport of baseball.

5. High School Baseball Player: an individual in the 15-18 years age range who participates in the sport of baseball for a freshman, junior varsity, or varsity level high school team.

6. College Baseball Player: an individual in the 18-23 years age range who participates in the sport of baseball for a college baseball team.

7. Modifiable Musculoskeletal Risk Factor: a measurable limitation in ROM, strength, and/or motor control that has been shown to increase risk for MSK injury yet responds favorably to common rehabilitation interventions.
8. **Physical Impairment**: a measurable limitation in ROM, strength, and/or motor control which does not fall within normal population specific values and limits an individual’s capacity to move, coordinate actions, or perform physical activities.

### 1.6 Assumptions

1. All baseline measures will be collected on the baseball player participants during off-season and pre-season team workouts.

2. Discussion of participant testing results were not discussed between coach raters during reliability testing.

3. All baseball player participants will perform their best effort during the testing procedures during data collection.

4. All baseball players will be medically cleared to participate in sport by a physician but may have underlying MSK risk factors that could lead to overuse injury.

### 1.7 Delimitations

1. All participants enrolled in the study continued to participate in team practice, workouts, and games unrestricted.

2. Musculoskeletal risk factors and impairments were determined by physical therapists using standardized procedures from previous literature.

3. All participants enrolled in the study were youth, high school, or collegiate baseball players from multiple schools located in Southern Indiana.

4. The screening results of one baseball coach were used as the reference standard for the discriminant validity in aim 3.
1.8 Limitations

1. Results from this project will not be generalizable to professional level baseball or female softball players.

2. Screening procedures were only able to identify the presence of a risk factor but unable to implicate a specific risk factor.

3. Diagnostic accuracy of the youth and college level players in aim 3 may be underrepresented due to low sampling power.

4. Prospective follow-up to determine injury risk predictive validity based on screening outcomes was not performed.

1.9 Abbreviations

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<td>Athletic Exposure</td>
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<td>MSK</td>
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<td>USA-BMSAC</td>
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<td>95% CI</td>
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<td>IRR</td>
<td>Injury incidence ratio</td>
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<td>Minimal Detectable Change at 95% level</td>
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CHAPTER 2. REVIEW OF LITERATURE

2.1 Purpose

Baseball players frequently place high throwing volume on an anatomical foundation which is unable to control and allow safe function because of inefficiencies and impairments throughout the kinetic chain. Important injury risk factors must be identified and mitigated with appropriate education and exercise programs otherwise the incidence of elbow and shoulder injuries will continue to rise. Therefore, the purpose of this literature review is to: 1) discuss the injury incidence in baseball players, 2) synthesize the known extrinsic injury risk factors associated with throwing volume and workload, 3) review important MSK intrinsic risk factors and impairments which could increase injury incidence throughout the kinetic chain, 4) review the effectiveness of the arm care exercise programs at reducing injury incidence, 5) discuss the need for a field expedient screening tool to identify meaningful physical impairments, and 6) present an approach to change coaching behavior and achieve adherence to screening and individualized arm care programming.

2.2 Injury in Baseball Players

Musculoskeletal injuries involving the shoulder or elbow are a considerable source of disability and time-loss from sport for baseball players. Repetitive overuse is thought to be a major contributor to injury among baseball players accounting for approximately one third of noncontact injuries.\textsuperscript{5,65} Upper extremity injuries are prevalent among all levels of baseball competition from youth to professional level players. The prevalence of injuries among professional level players is problematic as nearly 500 million dollars are spent on injured Major League pitchers annually.\textsuperscript{6} Although the implications
of this financial burden cannot be ignored, professional baseball players represent less than one percent of all baseball players, therefore, this literature review will focus on the 99% of baseball players who are youth, high school, or college level.

2.2.1 Youth

In youth baseball players the elbow is more commonly injured than the shoulder with an overall incidence rate of 1.5 injuries per 1000 AEs. However, the incidence rate specifically for youth pitchers was significantly higher at 2.5 per 1000 AEs suggesting that pitchers are more predisposed to injury compared to position players.49 Moreover, elbow injuries requiring emergency room visits are becoming more prevalent among adolescent baseball players.66 In a prospective cohort of 900 youth baseball players, Matsuura et al67 reported the 1-year cumulative incidence of developing elbow pain was 35.2%. In pitchers younger than 13 years old, Shanley et al68 reported a time-loss elbow injury incidence of 21.3% per baseball season. These results are consistent with the findings by Sakata et al49 who reported that 22.1% of youth baseball players developed medial elbow pain over a 12-month period. Unfortunately, elbow injuries more commonly warrant medical consultation from a physician, athletic trainer, or physical therapist. Over a 12-month follow up period, 40.6% (n=28/69) of youth pitchers with no prior history of elbow pain required medical consultation due to an elbow injury.49

2.2.2 High School

In high school baseball players, the shoulder is the most common site of injury accounting for 34.2% of reported injuries. The overall incidence rate for shoulder injury ranges from 0.139-0.172 per 1000 AEs in high school players.5 Muscle strains are the most common mechanism for injury with pitchers accounting for the largest proportion of
injury due to their susceptibility to repetitive overuse activity.\textsuperscript{5,69} Similarly, Shanley et al\textsuperscript{12} reported that pitchers were 3.6 times more likely to sustain an upper extremity injury compared to position players. Although catastrophic shoulder injuries requiring surgical intervention occurs in only 10\% of players, the majority of these players are pitchers.\textsuperscript{69} Fortunately, most high school baseball players with a shoulder injury will return to play within one week.\textsuperscript{13}

Elbow injuries in high school baseball players are less frequent accounting for 18.9\% of injuries.\textsuperscript{13} The overall incidence of elbow injuries among high school players is only 0.86 per 10,000 AEs.\textsuperscript{5} Although less common, when elbow injuries do occur they typically involve ligament strains and are more severe requiring several weeks to return sport.\textsuperscript{5} More alarming is that the number if ulnar collateral ligament reconstructions has disproportionally risen in 15-19 year old age group and is expected to continue to increase approximately 10\% over the next decade.\textsuperscript{22}

### 2.2.3 College

The injury rate for collegiate baseball players is higher compared to high school players.\textsuperscript{70} In college level baseball players, the overall injury incidence rate for all injuries is 5.83 per 1000 AEs. Twenty-five percent of all injuries are considered severe requiring greater than 10 days to return to sport.\textsuperscript{71} The incidence rate specifically for shoulder injuries was 4.02 (95\% CI, 3.50-4.60) per 10,000 AEs.\textsuperscript{65} Division I level players were 1.5 times more likely to endure a shoulder injury throughout the season compared to Division II or III players. Interpretation of the injury incidence ratio (IRR) suggests that shoulder injuries were 81\% (IRR=1.81; 95\% CI, 1.51-2.18) more likely to occur during competition compared to practice and 2.3 (IRR=2.34; 95\% CI, 1.3-4.06) times more
likely to occur in the preseason. The injury incidence rate for elbow injuries is 2.44 (95% CI, 2.90-2.85) per 10,000 AEs suggesting that shoulder injuries are more common in college players. Interestingly, surgery was required more often for elbow injuries and nearly twice as likely to be season ending compared to shoulder injuries. Although shoulder injuries are more common in college level players, elbow injuries are more severe requiring surgery and greater time loss.65

In general, shoulder injuries are more common in high school and college level players whereas elbow injuries are more frequent in youth players. Shoulder and elbow injuries are more likely to occur in pitchers,12,13,49,65 occur during live competition,65 and develop early in the baseball season.12,65 As a result, injury preventive efforts should be initiated prior to the start of the baseball season and closely monitored during the early weeks of competitive play as players are ramping up their conditioning, especially in pitchers. The onset of pain or injury is related to the presence of risk factors which could more than double the odds for a time-loss injury.49 Therefore, proper awareness and recognition of injury risk factors is critical for baseball coaches who wish to advocate for the health and well-being of their players.

### 2.3 Risk Factors Related to Overuse

There are several risk factors that have been associated with predisposing baseball players to upper extremity injury. These risk factors can be characterized as extrinsic or intrinsic risk factors. Extrinsic risk factors are related to the environmental demands in which the athlete performs while intrinsic risk factors are specific to the individual.41 Extrinsic risk factors commonly investigated in baseball players are associated with elevated
Baseball pitchers frequently engage in high levels of throwing volume that exceed the recommended safety guidelines. As a result, numerous studies have explored extrinsic injury risk factors related to pitching volume as the primary source related to overuse injury.

2.3.1 Pitch Volume

Recommendations based on how many pitches are allowed to be thrown by a single player in a game varies based on age. There appears to be a significant relationship associated with the number of pitches thrown in a game and the risk of developing shoulder pain. Lyman et al. found that youth baseball pitchers between the ages of 13-14 years old who threw more than 75 pitches in a game were over 2.17 times greater odds to develop shoulder pain. Furthermore, Olsen et al. reported a nearly four-fold (OR=3.83; 95% CI, 1.36-10.77) greater odds for shoulder or elbow injury related to throwing greater than 80 pitches in a single game in adolescent pitchers. Junior pitchers, aged 6-12 years, who threw more than 100 pitches in a single day were 1.96 (95% CI, 1.07-3.49) greater odds of sustaining a medial elbow injury.

In addition to guidelines relative to single game pitch counts, the cumulative effect of pitches thrown throughout the course of a season is also considered a significant extrinsic risk factor for injury. There is a direct relationship between the number of pitches thrown during a season and the odds of sustaining elbow or shoulder pain. The odds of sustaining an injury to the shoulder steady increases from 2.34, 2.90, and 3.29 relative to pitching 401-600, 601-800, and greater than 800 pitches in live competition per season, respectively. Typically the more pitches a player throws is related to a
greater number of innings accrued during the season. Fleisig et al\textsuperscript{20} reported that pitchers who threw greater than 100 innings per season were 3.5 times more likely to require arm surgery or discontinue their baseball career. It is possible that actual physical alterations occur as volume increases throughout the season which could affect the biomechanics of the throwing motion and lead to injury. High volume pitchers who throw more than 400 pitches per season experience a 13\% loss in supraspinatus strength from pre to post season.\textsuperscript{76} As a result, the deterioration of physical function is likely only more pronounced as players engage in year-round play.

2.3.2 Year-Round Pitching

The major concern for high volume pitching is the lack of required rest needed to fully recover prior to pitching again. In Major League Baseball pitchers, Whiteside et al\textsuperscript{19} concluded that rest periods between starts were just as important for reducing UCL injuries as monitoring pitch counts. As a result, it is generally recommended that pitchers abstain from pitching related activities for at least four months per year.\textsuperscript{24} Pitching greater than eight months per year increases the odds of injury five-fold (OR=5.05; 95\% CI, 1.39-10.77).\textsuperscript{4} More recently, abnormal and worsening postseason dominant shoulder MRI findings were associated with year round play and all-star team selection in youth players.\textsuperscript{77} It is becoming more common for players to play on multiple teams with different coaches throughout the year and specialize in a single sport making is difficult to achieve adequate rest from throwing.\textsuperscript{78} Coaches depend on the players and parents to discuss availability and physical well-being since communication with coaches from other teams can be challenging. However, players are highly motivated to participate in their sport and survey studies have suggested both players and parents are unaware of risk factors
and recovery periods.\textsuperscript{25,27} Thus, the cumulative effect of year-round play and undesirable rest and recovery may contribute to development of arm fatigue.

2.3.3 Arm Pain and Fatigue

Excessive throwing volume throughout the year incurred by pitching on multiple teams and regularly participating in showcases likely contributes to arm fatigue. Pitching with the throwing arm in a fatigued state has been associated with many negative consequences such as decreased proprioception and inability reproduce arm position,\textsuperscript{79} decreased dynamic stabilization of the shoulder,\textsuperscript{80} and shoulder muscle weakness.\textsuperscript{81} However, pitching through arm fatigue appears to be common with 75\% of players reporting that they frequently pitch with arm fatigue and pain.\textsuperscript{16} The likelihood for injury appears to increase drastically when performing while pitching with the arm in a fatigued state. Yang et al\textsuperscript{17} reported that the odds of sustaining a pitching related injury was 7.88 (95\% CI, 3.88-15.99) when pitching with the arm fatigued. Furthermore, pitchers who self-report that they “often” pitch with arm pain had 7.50 (95\% CI, 3.47-16.21) greater odds of having a pitching related injury.\textsuperscript{17} Similarly, Olsen et al\textsuperscript{4} reported that “regularly” pitching with the arm in a fatigued state was associated with 36.18 (95\% CI, 5.92-221.2) greater odds for sustaining an injury. Coaches and parents should monitor fatigue levels and pain specific to the throwing arm and respond with appropriate action to protect the health of the children.

Comparatively, youth pitchers who throw less often when their arm is fatigued have much smaller odds of injury. Pitchers who self-reported throwing “infrequently” when their arm was fatigued demonstrated no statistically significant greater odds (OR, 4.04; 95\% CI, 0.97-16.74) for a pitching related injury.\textsuperscript{4} Thus, coaches need to allow their
pitchers to obtain the proper rest needed to minimize the effects of routinely throwing when the arm is already in a fatigued state and more susceptible to injury.

Although not directly examined, it is reasonable to suggest a connection between increased throwing volume and onset of arm pain and fatigue. Routinely monitoring players for the development of these symptoms seems logical but implementing this practice presents with several barriers. Players may feel hesitant to report pain or fatigue due to the fear of being taken out of the game. Coaches may find it difficult to recognize symptoms of increasing fatigue and pain. Furthermore, coaches likely feel a great amount of pressure to be successful which may be related to their lack of adherence and knowledge of pitch count and rest guidelines. However, managing pitching volume and recovery is only a portion of the solution because physical dysfunction such as decreased mobility can also increase injury incidence.

2.4 Musculoskeletal Impairments in Baseball Players

The presence of key MSK impairments further compounds the problem of excessive pitching volume and likely exponentiates the overuse symptoms. Baseball coaches and sports medicine professionals cannot exclusively depend on managing throwing volume for injury prevention. Increased throwing volume and workload are plausible explanations for the continued rise in shoulder and elbow injury rates in pitchers, however, deterioration of physical function could also contribute to overall incidence of throwing related injuries. Researchers have identified several intrinsic risk factors which are inherent to the individual and can lead to development of injury. Although some intrinsic risk factors such as age and height are non-modifiable many intrinsic risk factors can be managed with intervention. Decreased ROM, strength imbalances,
asymmetries\textsuperscript{84,85} can manifest prior to the onset of symptoms or injury and typically can be modified with arm care exercise programs.\textsuperscript{40,86-88}

Baseball pitchers often present with anatomical differences due to adaptations from the overhead throwing motion. These adaptations commonly manifest as changes to the glenohumeral joint range of motion, humeral torsion, altered hip rotation mobility, decreased upper extremity strength, reduced single leg balance, and adaptative shortening of posterior shoulder muscles. These limitations can increase the demands on the throwing arm and result in increased stress on shoulder and elbow ligaments potentially leading to overuse injury. Several studies have evaluated the overhead thrower from a biomechanical perspective and determined that appropriate kinetic linking is necessary for optimal performance and decreased injury risk.\textsuperscript{34,37,89-91} Thus, identification of important MSK risk factors is a critical first step for baseball coaches to decrease injury rates in baseball players.

2.4.1 Glenohumeral Total Range of Motion

Measurable physical alternations associated with reduced shoulder ROM have been associated with decreased performance and increased risk of injury in overhead throwing athletes.\textsuperscript{92} It has been hypothesized that ROM changes in overhead athletes can be explained by shortening of the posterior shoulder muscles or deviations in bony humeral torsion.\textsuperscript{93} Humeral torsion typically increases through adolescence but can be reversed due to overhead throwing.\textsuperscript{94} Due to the throwing mechanism, baseball pitchers commonly present with decreased dominant arm humeral torsion which is synonymous
with increased retroversion.\textsuperscript{95} This osseous adaption results in ROM differences, specifically increased glenohumeral external rotation (GH ER) ROM and decreased glenohumeral internal rotation (GH IR) ROM compared to the nondominant shoulder.\textsuperscript{96,97}

Humeral torsion appears to be a normal physiological adaptation to pitching and likely does not increase risk for injury. In a systematic review and meta-analysis, Helmkamp et al\textsuperscript{98} reported no relationship between upper extremity injury risk and humeral torsion asymmetry in injured and non-injured baseball pitchers. However, there was a linear relationship between GH IR ROM and humeral torsion. As GH IR increases 1°, a subsequent increase of 0.65° in humeral torsion can be expected. Consequently, 65\% of GH IR ROM may be the result of non-modifiable bony adoptions to overhead throwing.\textsuperscript{98}

Although humeral torsion is not modifiable with exercise, reduced shoulder mobility which is not attributed to torsion can be improved by targeting soft tissue structures. Glenohumeral total range of motion (GH TROM) may provide a metric to gage the physiological shift in shoulder ROM in throwers. GH TROM is determined by adding the GH ER ROM and GH IR ROM on the dominant arm together while the participant is supine with the shoulder abducted to 90 degrees. This procedure is repeated on the nondominant arm so that a comparison between arms can be made. Asymmetrical GH TROM has been suggested to be a risk factor for elbow and shoulder injuries in baseball pitchers.\textsuperscript{1,46,82,99,100}

Evidence supporting the utility of GH TROM and injury risk has been reported in professional,\textsuperscript{99} college,\textsuperscript{101} high school,\textsuperscript{82} and youth\textsuperscript{40} level players. Researchers have re-
ported that GH TROM should result in no greater than a five degree asymmetry compared to the nondominant arm.\textsuperscript{99,102} In 369 major league baseball players, there was no difference between GH TROM measurements on dominant and nondominant arms.\textsuperscript{103} Wilk et al\textsuperscript{99} reported that professional baseball players with greater than five degrees of GH TROM deficit (GH TROM-D) were 2.6 (OR=2.6; 95% CI, 1.3-5.4, \( p=0.007 \)) times greater odds to be injured. Ruotolo et al\textsuperscript{101} reported an associated between college baseball players with a GH TROM asymmetry greater than 9.6° and the development of shoulder pain. In a 2018 systematic review and meta-analysis, Bullock et al\textsuperscript{100} reported that GH TROM less than 160° and asymmetries greater than 10° were both associated with increased injury risk. However, Bullock et al\textsuperscript{100} did not report the magnitude of the relative risk or odds for injury and included both high school and professional level players. Specifically, in high school baseball players, several prospective cohort studies have failed to associate GH TROM deficits with injury risk.\textsuperscript{46,47,68} Garrison et al\textsuperscript{104} reported that GH TROM-D were significantly greater in baseball players with a UCL injury compared to healthy players. However, this study was a cross-sectional design only assessing for an association and included both high school and college level players. Conversely, Shanley et al\textsuperscript{46} found that high school baseball players with a GH TROM-D exceeding 20° were associated with a three (RR=3.0; 95% CI, 1.1-8.4) times increased risk for developing an upper extremity injury. In youth baseball players ages 9-12 years, Sakata et al\textsuperscript{40} found that improving GH TROM was protective (OR=0.973; 95% CI, 0.950-0.997) for developing medial elbow pain during the season. GH TROM is a stronger injury risk factor in professional and collegiate level players but should continue to be monitored in adolescent and youth players due to its injury prevention implications.
2.4.2 Glenohumeral Internal Rotation Deficit

Anatomical adaptations to the throwing motion secondary to the extremely high demand of pitching results in GH IR ROM that will be asymmetrically decreased on the dominant arm of overhead athletes compared to non-overhead throwers. The term GIRD is commonly used to describe the difference between the nonthrowing GH IR ROM and the throwing GH IR ROM.\textsuperscript{33,105} However, the degree of acceptable GH IR asymmetry for baseball pitchers which is considered normal based on anatomical adaptions have been defined numerous ways. In a consensus statement, expert clinicians and researchers defined GIRD as a side-to-side asymmetry >18° between the dominant and non-dominant arm.\textsuperscript{33} More recently, Manske et al.\textsuperscript{106} described two conditions of GIRD: anatomical and pathological. Anatomical GIRD is defined as GH IR ROM loss of 18-20° on the dominant arm with a corresponding symmetrical GH TROM. However, pathological GIRD is defined as GH IR ROM loss > 20° with a corresponding GH TROM-D greater than five degrees.\textsuperscript{106}

As a result, reliable measurement procedures are warranted to capture changes in ROM throughout the season. Conventionally, the reliability of GH IR ROM is maximized using two evaluators with the participant in the supine position with the shoulder abducted to 90° with neutral forearm rotation, and the elbow flexed to 90°. A small towel roll is placed under the humerus to place the shoulder in the scapular plane approximately 10-15° anterior to the frontal plane.\textsuperscript{107} Appropriate stabilization is performed with a C shaped grasp (4 fingers on the posterior scapula and the thumb on the coronoid process) to control for scapular protraction and anterior tilt. Wilk et al\textsuperscript{108} reported that the C
shaped grasp demonstrated the greatest intra and inter-rater reliability compared to stabilization on the anterior shoulder or no stabilization. The examiner passively internally rotates the shoulder to the participant’s end range without adding addition overpressure to minimize overestimation due to excessive force. The measurement was taken with a standard goniometer with the axis at the olecranon process, the stationary arm along the midline of the forearm.46,107

Glenohumeral internal rotation ROM is key for normal force development during throwing and when limited can alter glenohumeral kinematics which is not ideal for athletic performance.109 Restricted shoulder internal rotation mobility limits energy transfer to the throwing arm during the pitching motion and requires greater effort to maintain throwing velocity which could increase stress on the upper extremity.92 As a result, the presence of a dominant side GIRD has been implicated as an injury risk factor in overhead throwers.100,110,111

The presence of GIRD as an independent injury risk factor for adolescent baseball pitchers has been debated in the literature. Multiple studies have explored the relationship between GIRD and upper extremity injury, however, many of these studies lack the ability to make observational associations due to cross-sectional designs. Trakis et al144 found no difference in preseason GIRD in asymptomatic adolescent pitchers with and without a history of throwing-related pain. Likewise, Chalmers et al72 reported that injured and uninjured adolescent pitchers did not differ in GH IR ROM. These previous studies only measured GIRD at preseason and retrospectively attempted to correlate the results with injury history. Thus, it is difficult to determine if GIRD was present prior to the onset of injury or if the injury itself caused the GH IR ROM loss.
Other researchers have explored the relationship between GIRD and baseball pitchers diagnosed with UCL injury compared to matched healthy controls.\textsuperscript{104,105,112} Ostrander et al\textsuperscript{105} reported that GH IR ROM loss did not differ between high school, college, or professional level pitchers. However, pitchers with a UCL tear had on average 21° of GH IR ROM loss compared to 13° of average GH IR loss in those without a UCL tear. Similarly in a retrospective case-control study, Dines et al\textsuperscript{112} reported that baseball players had significantly greater GIRD if they currently had a UCL tear compared to players with an intact UCL. Conversely, Garrison et al\textsuperscript{104} performed a prospective case-control study which found that high school and college baseball players with and without a UCL injury did not differ in GIRD. Unlike the study by Ostrander et al\textsuperscript{105} which only evaluated baseball pitchers, Garrison et al\textsuperscript{104} included pitchers, catchers, and position players. It is possible that including all players may have confounded the ROM findings as catchers and position players typically are not exposed to the same magnitude of throwing volume.

High quality prospective longitudinal studies are needed to establish clearer understanding of the predictive validity of limited GH IR ROM. Currently there are three prospective cohort studies in the literature which support GIRD as an independent injury risk factor in adolescent baseball pitchers.\textsuperscript{46,68,82} Shanley et al\textsuperscript{46} reported that dominant side passive GH IR loss of \(\geq 25^\circ\) was associated with a 3.7 (95% CI, 1.6-8.9) times greater risk for injury in high school baseball and softball players. However, this study was not representative of a homogenous sample as it included pitchers and position players who played both baseball and softball. Subgroup analysis of this study found that high school baseball pitchers with a GIRD \(\geq 25^\circ\) was associated with nearly a five-fold (RR=4.8;
95% CI; 2.1-11.3) increased risk for upper extremity injury. However, a GIRD ≥ 25° may not be a conservative enough cut point to maximize upper extremity injury risk detection. A prospective cohort by Shitara et al evaluated multiple risk factors with multivariate logistical regression analysis in high school baseball players. The presence of a 15° and 20° GIRD was associated with 2.1 and 2.7 greater odds for sustaining an upper extremity injury, respectively. Interestingly, a GIRD as minimal as 5° and 10° increased the odds for injury by 1.3 and 1.6 times, respectively. Additionally, Shanley et al used a receiver operator characteristic (ROC) curve to establish the optimal GIRD cut point which maximized sensitivity and specificity. Preseason GH IR deficits >13° in pitchers aged 13-18 years old were able to distinguish between injured and non-injured pitchers with an area under the curve (AUC) of 0.67. Greater than a 13° GIRD was associated with a nearly six-fold greater odds (OR=5.82; 95% CI, 1.6-20.9) of experiencing a loss time throwing related injury.

A GH IR asymmetry of 13° is much more conservative than the previously reported ≥25° cut value and is even less than the GIRD consensus definition of >18° which suggests that the magnitude of the GH IR asymmetry might not be as extreme as once thought. Two recent systematic reviews supported GIRD as an injury risk factor in baseball players. Bullock et al reported that absolute GH IR ROM less than 44° or more than a 5° asymmetry were associated with elevated injury risk in baseball players. Specifically, the presence of a measurable GIRD increases the odds for injury more than 5-fold (OR=5.93, 95% CI, 2.43-9.43). Likewise, Agresta et al reported a greater than two-fold increased odds for shoulder or elbow injury associated with GIRD.
Other studies have failed to support GIRD as an injury risk factor in adolescent baseball pitchers. In a case-control study, Tyler et al\textsuperscript{47} reported that high school pitchers who had $< 20^\circ$ GH IR loss were at greater than four times (RR=4.85, 95\% CI, 1.01-23.29) increased risk for experiencing a loss time injury. Interestingly, pitchers with $>20^\circ$ GH IR asymmetry were not at elevated risk for injury.\textsuperscript{47} This is in direct paradoxical opposition to other prospective research which has concluded that GH IR loss is associated with increased injury incidence.\textsuperscript{46,68,82} Norton et al\textsuperscript{114} conducted a systematic review specifically in adolescent baseball players and concluded that GIRD was not a risk factor.

Although the definition of GIRD has varied in the literature, typically depending on predictive cut points related to injury risk,\textsuperscript{46,82,105} the biomechanical implications and loss of mobility presents a physical characteristic which has been correlated to decreased isokinetic strength and poorer quality of life.\textsuperscript{8} Baseball pitchers typically observe loss of GH IR ROM following throwing as a result of increased stiffness in the posterior rotator cuff muscles. A reduction in dominant arm GH IR in adolescent overhead throwers appears to be meaningful and can result in increased odds for subsequent injury. Thus, GIRD may indeed be a risk factor that needs to be addressed in injury prevention programs.

### 2.4.3 Glenohumeral External Rotation Insufficiency

Anatomical reductions in GH IR ROM are accompanied with an expected increase in GH ER ROM on the dominant arm. GH ER insufficiency is observed when dominant arm GH ER ROM is less than five degrees greater than the nondominant arm.\textsuperscript{115} Players who do not demonstrate increased GH ER ROM on their dominant arm may place increased stress on static glenohumeral stabilizers.\textsuperscript{106} In a prospective cohort
study, Wilk et al\textsuperscript{115} reported that professional baseball players with a GH ER insufficiency of less than five degrees were 2.2 (95% CI, 1.2-4.1, \(p=0.014\)) and 4.0 (95% CI, 1.5-12.6, \(p=0.005\)) greater odds of sustaining a shoulder injury or requiring shoulder surgery, respectively. Furthermore, as the GH ER insufficiency becomes more pronounced beyond five degrees the odds or injury increases. Camp et al\textsuperscript{116} reported that the odds for an elbow injury increased 7\% for every 1 degree increase in GH ER insufficiency. GH ER insufficiency appears to be a meaningful injury risk factor but to date has only been studied in professional level baseball players.

Interestingly, adolescent baseball players between the ages of 7-18 years do not consistently demonstrate differences in GH ER ROM. Four studies\textsuperscript{47,49,82,117} have failed to support GH ER ROM as an independent risk factor in adolescent baseball players. More recently, Shitara et al\textsuperscript{118} conducted a multivariant regression analysis which showed that limitations in GH ER ROM was an independent risk factor among youth baseball players. Regardless, to date support for GH ER ROM limitation as an independent risk factor for MSK injury youth, high school, and college level players is limited.

2.4.4 Thoracic Rotation Range of Motion

The contribution of trunk rotation during the pitching motion has been well documented in the literature as a necessary component for optimal throwing performance.\textsuperscript{119-121} An appropriate connection between the lower extremities, spine, and upper extremity must be established for optimal energy generation and transfer to occur.\textsuperscript{121,122} Poor mobility in the thoracic spine can attenuate this process and alter throwing mechanics.\textsuperscript{121} Without sufficient thoracic ROM, specifically in the sagittal and transverse planes, maximal force generation is difficult to achieve. During the wind-up phase of the throwing motion
the thorax must extend and rotate toward the throwing arm. Maximal shoulder external rotation ROM is achieved during the late cocking phase and the stored kinetic energy from the thoracic rotation is released as the spine flexes and re-rotates back toward the throwing arm. This elastic uncoiling of the spine produces the force generation required for the acceleration phase of pitching as the energy is focused toward the intended target. However, poor thoracic mobility has shown to produce biomechanical faults and altered kinematics at the shoulder and elbow which could increase the physiological stress on these joints.

The mobility of the entire upper quarter including the glenohumeral joint, scapula, and thoracic spine make considerable contributions to achieving maximal shoulder external rotation ROM during the late cocking phase of pitching. The glenohumeral joint cannot be expected to function in isolation. The spine provides the connection between the upper and lower quarter to generate the power required for the acceleration phase of throwing. Therefore, the ability to accurately quantify spinal rotation mobility is important for rotational sports such as baseball to determine if adequate mobility is present for proper kinetic linking.

Approximately 80% of spinal rotation mobility occurs in the thoracic spine region. Consequently, clinical tests have attempted to evaluate isolated thoracic spine rotation by minimizing the contribution of the lumbar spine. The “lumbar locked” thoracic rotation test has demonstrated good to excellent intra-rater (ICC= 0.86-0.96) and inter-rater reliability (ICC = 0.87-0.89) in the quadruped posture with the hips in full flexion to reduce the lumbar involvement. Bucke et al used an ultrasound motion capture system to explore the criterion validity of the “lumbar locked” thoracic rotation test.
There were strong correlations between ultrasound motion capture analysis and goniometric measures taken with the iPhone clinometer application ($r=0.88$) and a digital inclinometer ($r=0.88$). Other versions of thoracic rotation testing have been performed in seated and half kneeling positions. Although these tests demonstrate good reliability, they are performed with the hips flexed to only $90^\circ$ which does not fully reduce the lumbar spine contribution.\textsuperscript{130,133,134}

Poor movement at the thoracic spine can disrupt the kinetic chain sequence, lead to undesired compensation of the low back and shoulder girdle, and lead to MSK injury.\textsuperscript{135,136} In a prospective cohort, Sakata et al\textsuperscript{49} identified an increased thoracic spine kyphosis angle as a significant predictor for medial elbow pain in youth baseball players. Multivariant logistic regression found that baseball players with a thoracic kyphosis angle $\geq 30^\circ$ had a 2.5 (OR=2.5; 95% CI, 1.381-4.531) times greater odds for medial elbow pain.\textsuperscript{49} Furthermore, two prospective studies have demonstrated that improvement of thoracic spine mobility over the course of a baseball season is associated with reduced injury incidence.\textsuperscript{40,86}

2.4.5 Hip Rotational Range of Motion

The lower quarter has been implicated in contributing to injury risk when not functioning ideally. The throwing motion is complex sequence of multi-joint movements in which the hips are critically important for proper energy transfer from the lower body to the upper body during the throwing motion. Limitations in hip ROM can alter the biomechanics of the throwing motion and place increased stress on the shoulder and elbow joint during the throwing motion.\textsuperscript{137} Several studies have supported the concept that the
hips can influence upper extremity function and increase injury incidence among baseball players of all age levels.

Researchers have explored hip rotational ROM limitations as potential injury risk factors at the professional\textsuperscript{138,139} and collegiate,\textsuperscript{140} high school,\textsuperscript{141} and youth\textsuperscript{142,143} age levels. Hip rotational ROM limitations among professional level players have been more associated with lower extremity injuries. Camp et al\textsuperscript{138} reported that a hip internal rotation (hip IR) deficit of greater than five degrees was associated with 1.40 (95% CI, 1.01-1.79) greater odds of abdominal or low back injuries in 258 major league baseball players. Interestingly, in the same study hip rotation deficits were not associated with upper extremity injuries in pitchers. Similarly, Li et al\textsuperscript{139} demonstrated that decreased hip IR ROM and total range of motion were associated with strains to the groin, hamstrings, and hips in professional baseball players.

The link between hip rotation mobility limitations and upper extremity injury incidence has also been explored in adolescent baseball players. Sekiguchi et al\textsuperscript{144} reported that stride hip IR ROM < 36° was associated with elbow or shoulder pain (OR=1.08; 95% CI, 1.01-1.15) in 210 youth baseball players. Saito et al\textsuperscript{142} found that adolescent baseball players with current elbow pain have approximately 10 degrees less hip IR ROM compared to players without elbow pain. The implications of injury risk and limited hip external rotation (hip ER) ROM has not been as robustly studied. However, Hamano et al,\textsuperscript{141} reported that stride hip ER ROM less than 40 degrees was a risk factor for developing shoulder or elbow pain during the season in high school baseball pitchers. Logistic regression showed that for every 1° increase in hip ER ROM injury risk decreases by an odds ratio of 0.89.
There is evidence of a relationship between increasing pitching volume and declining hip function throughout the season. Similar to the glenohumeral joint, adaptations in hip rotational mobility can also occur throughout the course of a season. In a longitudinal cohort study, Zeppieri et al reported that hip ER ROM and hip total ROM (hip IR + ER) for both the lead and trail legs decreased from pre to post season. The lead and trail leg exhibited a hip ER ROM decrease of 7.9 +/- 10.2 and 10.3 +/- 7.2 degrees in the lead and trail leg by the end of the season, respectively. However, these hip ROM changes did not correlate with increased pitching volume but a small sample size of 14 participants lacked sufficient power and increased the likelihood for a type II error. Conversely, Harding et al found moderate correlations between pitching more innings per game ($r=0.53$) and throwing more pitches per game ($r=0.62$) and decreased ipsilateral hip ER ROM in youth and high school baseball pitchers. Interestingly, reduced pitching volume was strongly correlated to increased contralateral hip IR ROM ($r=0.79$). It is possible that less exposure to pitching may minimize the development of hip IR ROM deficits.

2.4.6 Single Leg Balance

The lower extremities establish a stable proximal base of support which allows efficient force generation in the upper extremities. In addition to lower body strength and ROM, single leg balance is required for optimal pitching mechanics due to the direct effect the kinetic chain has on adjacent body segments. Sufficient single-limb balance time has shown to increase the transfer of the body’s momentum toward home plate during the throwing motion. Deficits in single leg balance lead to poor lumbopelvic control and can disrupt the kinetic sequencing of throwing motion and require a greater contribution
from the upper extremity to develop the force needed to preserve pitching performance.\textsuperscript{148} Specifically, overdependence on the glenohumeral joint due to lack of lower quarter contribution could produce forces that exceed the failure capacity of important anatomical structures such as the UCL.\textsuperscript{149,150}

The ability to maintain dynamic single leg balance near the limits of one’s stability can be represented in their stride length. Stride length has been thought to measure the effectiveness of a pitcher’s ability to use the entire kinetic chain.\textsuperscript{147} Post et al\textsuperscript{151} reported that adequate stride length could assist in allowing for maximal pitching velocities without increasing the forces on the upper extremity joints. Culiver et al\textsuperscript{152} reported that college baseball players who had better single leg balance demonstrate increased stride length during the pitching motion. There was a moderate positive correlation between dominant \((r=0.524)\) and non-dominant leg \((r=0.550)\) Y Balance Test-Lower Quarter (YBT-LQ) composite scores and stride length suggesting better dynamic balance is related to increased stride length. Likewise, stride length has been shown to be positively correlated \((r=0.458)\) with time to maximal humerus velocity during the throwing motion.\textsuperscript{152} Pitchers who throw with altered muscle sequencing and kinetic linkage may need to achieve maximal humerus velocity earlier to compensate for decreased lower quarter contribution.\textsuperscript{152} Thus, pitchers who demonstrate decreased stride length depend more on force generation from the upper extremity which may increase stress to the shoulder and elbow.\textsuperscript{147}

The concept of single leg balance as a potential upper extremity injury risk factor has mainly been examined in collegiate and professional baseball players in cross sectional and retrospective study designs.\textsuperscript{85,148,152-154} In high school and collegiate baseball
pitchers diagnosed with a UCL tear, composite scores on YBT-LQ were approximately 5-6% worse on both legs compared to those without an UCL tear.\textsuperscript{85,153} Although the retrospective design of this study makes it difficult to implicate single leg balance as the direct connection to UCL injury.

The literature of deficits in single leg balance and injury risk in adolescent baseball players is limited, however, the kinematics of the lower quarter during the throwing motion are similar relative to collegiate pitchers.\textsuperscript{155} In youth baseball players, Endo et al\textsuperscript{156} reported no clear differences in dynamic balance scores on the Star Excursion Balance Test (SEBT) and players with elbow and shoulder pain. Similarly, Sekiguchi et al\textsuperscript{144} found that SEBT scores were not associated with pitchers with elbow or shoulder pain. However, Schroeder et al\textsuperscript{50} reported YBT-LQ composite scores decreased 3.15% on the stance leg and 4.34% in the lead leg immediately following pitching. Additionally, following pitching 28.6% of the players changed to a higher injury risk category based on the Move2Perform software.\textsuperscript{50} Lehr et al\textsuperscript{157} validated the Move2Perform software as an injury risk algorithm which takes into consideration current pain, previous injury history, balance asymmetries, and YBT-LQ composite performance relative to an individual’s age, gender, and sport. Individuals who were classified into the “high risk” category were at a 3.4 (RR=3.4; 95% CI, 2.0-6.0) times increased risk for future injury.\textsuperscript{157} Interestingly, reductions in dynamic balance occurred even though all players only threw an average of 30 pitches and did not exceed pitch count guidelines based on their age group.\textsuperscript{50} The immediate changes observed in glenohumeral ROM directly following pitching is well documented but it is possible that lower extremity function and core balance/neuromuscular control may also require monitoring and appropriate intervention throughout the season.
Upper extremity pain and injury in baseball players is associated with numerous MSK risk factors, which presents as measurable impairments throughout the kinetic chain. Baseball coaches must begin to look beyond just the upper extremity as the only source for injury but also consider more remote regions of the body which also contribute to injury incidence. Awareness of MSK injury risk factors is fundamental for development of injury prevention programs to manage pathological dysfunction prior to the development of symptoms and loss time injury.

2.5 Arm Care Exercise Programs

Baseball coaches and sports medicine professionals have recommended and utilized exercise programs targeting strength and flexibility of the throwing arm in an attempt to prevent injuries.\textsuperscript{15,42-44} These arm care exercise programs vary considerably but they follow four principles; 1) identify risk factors, 2) define cut off values for the risk factors based on normative data, 3) assessment and reassessment procedures that are reliable and valid, and 4) implementation of preventative exercise programs.\textsuperscript{43} More recently researchers have begun to investigate if proper management of specific MSK impairments could result in injury risk reduction.\textsuperscript{44,86,88,158,159} Theoretically, managing risk factors could result in decreased injury rates and associated time lost from sport.

Musculoskeletal limitations or inefficiencies throughout the kinetic chain can result in excessive physiological stress in the throwing arm.\textsuperscript{37,91,160} To address these deficiencies, arm care exercise programs have been developed\textsuperscript{40,86,88,161} to improve strength, dynamic stability, and ROM of the muscles and joints important to the throwing motion and related to shoulder and elbow health in overhead athletes.\textsuperscript{161} Historically, arm care exercise programs began as generalized upper body strengthening or targeted stretching
to a particular muscle group. More recently, these programs have evolved to target multiple physical impairments throughout the kinetic chain and use screening to individualize program design. However, to date there is a limited number of prospective clinical trials which have explored the effectiveness of arm care exercise programs at reducing injury risk in overhead athletes.40,86,88

2.5.1 Upper Extremity Strengthening

The benefit of including shoulder strengthening exercises in arm care programs for injury risk reduction is unclear in the literature among high level of evidence (LOE).162 In a prospective cohort (LOE 2), Shitara et al82 identified that external rotator weakness, measured as a ratio between dominant and non-dominant arms, was associated with up to 7.3 greater odds for injury in high school baseball players. However other high-quality evidence, two LOE 248,49 and one LOE 3,47 have not supported decreased absolute shoulder strength or external rotator strength ratio as injury risk factors in adolescent baseball players. According to Sakata et al,49 deficits in external rotation, serratus anterior, or lower trapezius strength ratios were related to elbow injury in youth baseball players. Likewise, Tyler et al,47 reported that pre-season deficits in GH ER, GH IR, or supraspinatus weakness were unrelated to upper extremity injury in high school baseball players. However, inconsistencies in testing positions may have contributed to the variation seen in these results. Specifically, Tyler et al47 measured shoulder ER strength in a supine position and reported the absolute strength deficit whereas Sakata et al49 and Shitara et al82 measured ER weakness in prone and reported the ratio of ER and IR weakness.
The thrower’s ten exercise program is a commonly used shoulder and elbow strengthening program\textsuperscript{163,164} which has been recommended as an injury prevention program.\textsuperscript{42,165,166} The program is based on electromyographic (EMG) data which implicates specific exercises to best achieve meaningful muscle activation and strengthening of the shoulder girdle and elbow musculature.\textsuperscript{166,167} The thrower’s ten program and more recently the updated advanced thrower’s ten exercise program\textsuperscript{161} has been found to improve key performance metrics important to baseball pitchers, such as shoulder strength and endurance\textsuperscript{168} and pitching velocity.\textsuperscript{169} However, the ability of the thrower’s ten to reduce injury risk appears to be unknown. To date, no published studies have investigated injury risk reduction outcomes associated with the thrower’s ten or advanced thrower’s ten exercise programs in baseball players. Further research is needed to quantify the degree to which shoulder strength deficits contribute to injury risk and explore if the thrower’s ten program can decrease injury incidence in baseball pitchers.

2.5.2 Shoulder Stretching

As one of the most studied areas, shoulder mobility deficits or adaptations to throwing are commonly observed and may be risk factors for injury. Restricted GH IR mobility limits energy transfer to the throwing arm during the pitching motion and requires greater effort to maintain throwing velocity which could increase stress on the upper extremity.\textsuperscript{92} The presence of GIRD has been associated with biomechanical faults in high school pitchers, such as greater trunk tilt and less trunk rotation.\textsuperscript{92} A dominant side GIRD has been proposed as an injury risk factor in overhead throwers.\textsuperscript{100,110,111} Shanley et al\textsuperscript{46} (LOE 2), found that high school baseball players who had GIRD of greater than 25 degrees in their dominant shoulder were at nearly five times (RR=4.8; 95% CI, 2.1-11.3)
greater risk for injury. It appears that GIRD may be an important MSK adaptation in baseball pitchers and proper management with posterior shoulder stretching can reduce upper extremity injury risk.

In a prospective cohort (LOE 2), Shitara et al.\(^8\) examined the outcome of an injury prevention program in reducing shoulder and elbow injury risk over the course of a competitive baseball season (150 days) in 92 high school baseball pitchers. These researchers compared the difference in incidences of upper extremity injury defined as, ≥ eight days of disability, between shoulder self-stretching for GIRD and posterior shoulder external rotator strengthening for rotator cuff weakness. Stretching the posterior shoulder muscles daily by performing the “sleeper stretch” to improve GH IR ROM was associated with a 36% (HR=0.355, 95% CI, 0.133-0.947) shoulder and elbow injury risk reduction.\(^8\) The overall incidence of shoulder and/or elbow injury for pitchers who performed posterior shoulder stretching compared to pitchers who did not was 25% (n=8/32) and 57% (n=8/14), respectively. Additionally, time-to-event analysis showed that pitchers who performed daily sleeper stretching were able to pitch three times longer throughout the season compared to those who did not perform daily preventive stretching.\(^8\) Although rotator cuff weakness has been suggested as an injury factor for high school pitchers,\(^47,82\) Shitara et al.\(^8\) found that posterior shoulder stretching alone was more effective than the addition of external rotator strengthening at reducing incidence of injury.

2.5.3 Multimodal Group Arm Care Programs

More recently, arm care programming has expanded beyond the narrow focus of one or two injury risk factors by evolving into comprehensive programs which target multiple impairments throughout the entire body. Throwing a baseball is a full body
movement pattern and requires appropriate linkage between the upper and lower body.\textsuperscript{160} Several authors have evaluated the overhead thrower from a biomechanical perspective and determined that appropriate kinetic linking is necessary for optimal performance and decreased injury risk.\textsuperscript{34,37,89-91} Important MSK deficits that have been identified as potential injury risk factors for adolescent baseball players include GIRD,\textsuperscript{46,82} GH TROM,\textsuperscript{40} decreased hip IR ROM,\textsuperscript{40,86} poor thoracic posture,\textsuperscript{40,49} and deficits in single leg balance.\textsuperscript{170} Arm care programs focusing on full body strength and ROM maintenance are likely more advantageous for injury prevention because they address multiple risk factors or impairments.\textsuperscript{4,72,171}

Preventative programs which target multiple known risk factors have shown promise in improving physical impairments and reducing injury rates in youth baseball players.\textsuperscript{86,159} Two high quality prospective studies have been published delineating the effectiveness of an injury prevention program in youth baseball players.\textsuperscript{86,159} In a 2018 non-randomized controlled trial (LOE 2), Sakata et al\textsuperscript{159} reported a 49.2% (HR=50.8%; 95% CI, 0.29-0.88) reduction in the incidence of medial elbow pain in 305 youth baseball players after a preventative program targeting strength and ROM of the shoulders, hips, and spine. The injury prevention program, called the Yokohama Baseball-9 (YKB-9), was performed 2x/week and consisted of a total of 18 exercises (nine strengthening and nine stretching) designed to improve multiple risk factors throughout the kinetic chain. Improvement of MSK injury risk factors resulted in an incidence of 0.8 per 1000 AEs in the athletes who performed the prevention training compared to 1.7 per 1000 AEs in those who did not participate. Multivariate logistical regression identified improvement in GH TROM, decreased thoracic kyphosis angle, and increased stride hip IR ROM were
the most important MSK impairments associated with predicting success in preventing elbow injuries. These findings are consistent with other research which has implicated decreased GH TROM, poor thoracic spine ROM, and limited hip IR ROM as important impairments which could increase risk for injury. In a 2018 systematic review and meta-analysis, Bullock et al reported that GH TROM less than 160 degrees and asymmetries greater than 10 degrees were both associated with increased injury risk. In a LOE 2 study, an increased thoracic kyphosis angle of greater than 30 degrees was associated with a two-fold increased risk for injury in youth baseball players. Limited hip IR ROM, which seems remote to the throwing shoulder, has also been associated with increased risk for development of medial elbow pain.

In 2019, the original YKB-9 program was modified to be less complex and time intensive. The modified YKB-9 (mYKB-9) program reduced the number of exercises from eighteen to nine, but still consisted of 1) stretching for the elbow, shoulder, and hip, 2) dynamic mobility for the scapula and thorax, and 3) lower body balance. The effectiveness of the mYKB-9 program was evaluated in a clustered randomized controlled trial (LOE 2) at reducing elbow and shoulder injuries in a cohort of 237 youth baseball players. At 12-month follow-up, the incidence of shoulder/elbow injuries was significantly lower in the athletes who completed the mYKB-9 program compared to those who did not participate (HR=1.94; 95% CI, 1.17-3.2). Specifically, those who did not participate in the mYKB-9 program were nearly two times more likely to experience an upper extremity injury. Furthermore, there was a 48.5% reduction in risk for shoulder or elbow injury associated with participating in the mYKB-9 program compared to the control group.
This reduction in overuse elbow injury is consistent with the results found by Sakata et al in 2018.\textsuperscript{86}

Compared to the original YKB-9, the mYKB-9 program which included half as many exercises resulted in an overall adherence rate improvement from 57.4\% (n=78/136) to 73.4\% (n=89/109). Athletes who demonstrated high adherence with the injury prevention program had an elbow injury incidence 0.5 per 1000 AEs compared to 1.2 per 1000 AEs in those who had low adherence.\textsuperscript{86} The simplification of mYKB-9 program greatly improved adherence while not compromising effectiveness, suggesting that fewer but more targeted exercises can still achieve similar reductions in injury incidence.

2.5.4 Individualized-Group Arm Care Programs

Injury risk is multifactorial\textsuperscript{40,49,82} and since each individual baseball player could possess unique impairments, it seems logical to individualize arm care programs to maximize benefit. Shoulder pain in overhead athletes is commonly associated with various MSK movement changes, which can present as measurable impairments in the upper and lower quarter, but may manifest differently in each player.\textsuperscript{34,172,173} In general, group-based programs are limited in depth by only focusing on single risk factors or specific injuries.\textsuperscript{174} The 48.5\% injury incidence reduction as seen in mYKB-9 is encouraging, but there still remains room for improvement as a large proportion of baseball players still sustained an overuse injury.\textsuperscript{86} Individualized arm care programs could address multiple MSK impairments and appropriately distribute the exercises based on the need of the player, potentially creating a better avenue for greater injury risk reduction.

In a LOE 2 study, Huebner et al\textsuperscript{175} found that 50\% of high school soccer players were able to advance from “high” to “low” risk based on the Move2Perform injury risk
categorization algorithm following an eight-week individualized injury prevention program. Lehr et al validated the Move2Perform software as an injury risk algorithm which includes current pain, previous injury history, FMS performance, and YBT-LQ asymmetries and composite score relative to an individual’s age, gender, and sport. Individuals who were classified into the “high risk” category were at a 3.4 (RR=3.4; 95% CI, 2.0-6.0) times increased risk for future injury. Using pre-season screening, Huebner et al assigned a combination of three strengthening and stretching exercises that were performed during the warmup and cool down based on the individual’s FMS score. The remaining components of the program consisted of a group-based plyometric, agility, and core training program that was similar for all athletes. Interestingly, individuals who reported pain during screening were unlikely to make a categorical improvement. This suggests that when screening produces pain, a group-based program is not individualized enough to reduce injury risk and appropriate referral to a health care provider for a detailed assessment should be considered.

2.5.5 Screening for Musculoskeletal Impairments

Sports medicine professionals commonly use movement screening to identify individualized physical impairments in baseball players. Two movement-based screening tools that exist are the FMS and the Selective Functional Movement Assessment (SFMA). The FMS and SFMA are designed to identify major limitations and/or asymmetries which could contribute to MSK pain or movement deficits. The FMS is mainly implemented for individuals with no known orthopedic issues while the SFMA is utilized for individuals who have current pain. Both the FMS the SFMA have
demonstrated moderate levels of intra-rater and inter-rater agreement among live tester in multiple populations.\textsuperscript{182-187}

Frequently limitations in ROM, strength imbalances, or asymmetries can manifest prior to the onset of symptoms or injury. Researchers have previously studied components the FMS and SFMA as preseason movement-based screens in high school and collegiate baseball players as a way to predict injury risk.\textsuperscript{84,188,189} Poor performance on the FMS shoulder mobility patterns was associated with an adjusted odds ratio of 5.14 (95% CI, 1.14-22.9) of having an overuse injury during the preseason.\textsuperscript{84} Additionally, poor performance on the SFMA upper extremity pattern tests was associated with increased odds of overuse symptoms. Specifically, identified dysfunction in either the unilateral shoulder extension/internal rotation pattern or the unilateral shoulder flexion/external rotation pattern was associated with an adjusted odds ratio of 6.10 (95% CI, 1.22-30.55) and 17.07 (95% CI, 13.9-210.2) during both the preseason and competitive season, respectively.\textsuperscript{84} Moreover, the previous study only included the shoulder mobility components of the FMS and SFMA and failed to include important lower quarter impairments, specifically hip rotation mobility and dynamic balance.

In most circumstances high school coaches are limited in the staffing and resources needed to perform movement screenings on their players. Furthermore, the FMS requires testing equipment and takes about 10 minutes to perform on each player.\textsuperscript{32} The SFMA is a clinical assessment designed for practitioners with a license to diagnose and treat pain\textsuperscript{28} and therefore is out of the scope of practice for the coach. As a result, high school coaches may be discouraged to implement screening for their players due to the feasibility restraints. Thus, there is a need for a field expedient screening tool which
can identify impairments throughout the entire kinetic chain that can quickly be administered by the coach. Consequently, coaches assuming a greater role in injury prevention would require a willingness to adapt their coaching philosophy and behavior to meet the demands of screening and individualized arm care programs.

2.6 Developing Adherence to Screening and Injury Prevention

For nearly two decades overuse from increased pitching volume and limited upper extremity function have been linked to injury rates. Yet, injury rates have not decreased which calls into question adherence to implementation of the recommendations needed to modify injury risk factors.\(^5\) Adherence is a multifaceted behavioral response determined by multiple interacting variables including both individual and organizational factors. However, researchers have found that simply providing awareness of injury prevention strategies is generally ineffective at promoting adherence. Despite pitch count guidelines, many youth baseball coaches remain limited in their knowledge and application of these recommendations.\(^26\) Without a fundamental behavioral change and improved adherence to screening and arm care exercise programs a significant public health impact is unlikely to occur.

In a proposed framework adapted from van Mechelen et al,\(^190\) adherence achievement is modeled in a four-step sequence, 1) identifying adherence rates, 2) describe predictors of adherence or non-adherence, 3) develop strategies for improving adherence, and 4) reevaluate the adherence rates.\(^191\) Arguably the most critical component of this sequence would be developing effective strategies for promoting satisfactory adherence. Improving adherence requires a balance of evidence-based education and consideration
for the real-world practicality of implementing screening and individualized arm care exercise programs.  

2.6.1 Educating Coaches on Delivery of Injury Prevention Programs

There is a paucity of literature examining player adherence to injury prevention programs delivered by the coach and the quality to which the corresponding exercises are being performed by the players. To date, the most robust exploration of adherence rates in sports was conducted in Canadian football players (American soccer). In a clustered-randomized controlled trial of 385 athletes, Steffen et al. reported that adherence rates to a group-based injury prevention program were best when delivery by the coach who had extensive training and education in the program. Specifically, adherence to the injury prevention program was 85.6% when led by a well-educated and supervising coach compared to only a 73.5% adherence rate when the coach lacked formal training and did not supervise the players. Interestingly, the additional assistance of a supervising physiotherapist was equally as effective at achieving high adherence as a well-educated supervising coach led session alone. Players who view their coach as effective are typically more committed to the overall coaching philosophy and more willing to make a behavioral change. Thus, successful adherence is likely dependent on the hierarchy of importance the coach places on screening and arm care programming. As a result, continued investment in coaching education, hands on workshops, and other educational resources are paramount to effective player adherence to prevention exercise protocols.

2.6.2 Practicality of Screening Implementation

Designing individualized arm care exercises programs would require large scale commitment to player screening and proper execution of the interventions which may not
seem realistic in some settings. Coach behavior could be improved by increasing the ease of implementation of screening and individualized arm exercise. Establishing communication with the coach to identify the team’s specific goals and needs can aid in building a program which is feasible and meaningful. Consideration for each team’s situational circumstances specifically regarding access to equipment, time allowance, and staffing can engage the coach to begin the process of behavioral change.

2.6.3 A Model for Achieving Behavior Change in Baseball Coaches

Although coaches generally agree that injury prevention programs are effective and express intent to implement preventative strategies, actual adoption of these programs is largely underwhelming. Education and acceptance of the positive benefits of a program does not always imply that a behavioral change will occur. Current research is lacking specifically identifying strategies for facilitating a behavioral change in coaches regarding injury prevention implementation. The transtheoretical model of change describes modification of behavior as a dynamic process which occurs in a stepwise manner and can either progress or regress over time. This model conceptualizes the behavioral change process through five stages: precontemplation, contemplation, preparation, action, and maintenance. The transtheoretical model of change has been an effective framework for smoking cessation and weight loss management, however, this model has not been applied to baseball coaches or injury prevention.

The transtheoretical model applied to an injury prevention initiative which implements MSK screening and individualized arm care exercises could assess the coaches’ readiness to transition to a new behavior and provide strategies to achieve the intended
behavior. Coaches may begin at different stages of the process, but specific interventions are recommended for transition to the next stage and prevent relapse.198

**Stage 1 – Precontemplation:** Individuals in the precontemplation stage are not intending to make an actionable behavioral change in the foreseeable future.198 Baseball coaches in this stage may be unaware of the benefits associated with implementing screening to inform individualized arm care programs. Stage transition is dependent on collaborative efforts from rehabilitation professionals to provide the coach with educational awareness of field expedient screening and the potential benefits of arm care programs.204 The coach will likely require encouragement to focus on the positive benefits of the new behavior and not dwell on the negative effects. It is particularly important not to display overly authoritarian communication while educating those in precontemplation.205 Careful motivational strategies to bring awareness to problems within their team, such as a poor player durability, may engage the coach to consider a new behavior.

**Stage 2 – Contemplation:** Individuals in the contemplation stage understand the positives of the behavioral change and intend to take action in the near future.198 Many coaches can be categorized in a contemplative state as they typically acknowledge the benefits of injury prevention but fail to action on implementation.45 Frequently individuals in this stage may focus on the barriers to implementation such as limited resources, personnel, or time. Stage transition can be achieved by identifying the coach’s perceived modifiable and non-modifiable barriers to implementation.205 Although some barriers are indeed non-modifiable, most can be overcome or minimized with proper planning or innovative solutions which allow for quick screening without additional equipment or staff.
Stage 3 – Preparation: Individuals in the preparation stage are intending to take action and have developed a plan necessary for change. Coaches in this stage have allocated responsibility of screenings to their staff and outlined specific exercises including volume, frequency, and intensity to develop their arm care program. It is important that the coaches view the change as in their best interest to prevent relapse. However, barriers which were theoretically resolved in the contemplative stage, or that were unforeseen may present as additional challenges as the practical structure of the implementation plan takes form. In this stage, it is important to prevent relapse by providing social support for the coach and aiding in problem-solving strategies.

Stage 4 – Action: Individuals in the action stage have recently implemented the behavior change concepts into practical application. During this stage, the coach is demonstrating a commitment to change by using screening to inform individualized arm care exercise programs. However, this new behavior it still in its inaugural season and is vulnerable to not being maintained long-term. Routine check-ins with the coach as the system is being implemented is important to develop accountability. Coaches in this stage may question if the program is worthwhile, therefore, it is important to provide positive reinforcement and reflect on the success of the program. Specifically, the metrics which the coach perceives are important to the overall team success should be reviewed. This may include the team’s record, player durability, or individual player statistics. In the event of suboptimal outcomes, the program should be reviewed and altered to achieve the coach’s desired outcomes. However, success in the program should be highlighted and the coach should be encouraged to reward themselves for their progress.
Stage 5 – Maintenance: Individuals in the maintenance stage have successfully maintained the desired behavior change for an extend period of time, usually greater than six months.\textsuperscript{198} Coaches in the maintenance phase have continued to implement screening and individualized arm care programming for a second consecutive season. The coaches are more autonomous and fully committed to this behavioral change.\textsuperscript{198} No outside supervision beyond the coaching staff is required for accountability or to maintain the behavioral change. At this point relapse is less likely but continued social support and improved self-efficacy will discourage regression.\textsuperscript{206}

2.7 Frequent Screening to Adjust for Variable Change in Baseball

Screening tests conducted in the preseason provide an accurate depiction of the current physical state of the athlete. However, the MSK function of athletes is constantly fluctuating and can respond differently based on the demands of sport.\textsuperscript{207} Specifically, important MSK impairments or risk factors may not be present at preseason but could develop as the season progresses. Critics of MSK screening suggest that a singular test cannot account for the multiple changing variables with a consistent degree of sensitivity to be universally implemented.\textsuperscript{208} Thus, predictions regarding injury risk are narrow focused when assuming MSK risk factors remain constant throughout the season.

Researchers have begun to discuss a more dynamic and nonlinear model to injury prevention.\textsuperscript{207,209,210} These more sophisticated models imply that multiple variables are responsible for the development of an injured state, however, the variables themselves are constantly changing as an adaptation of the individual’s environment or unique demands of the sport.\textsuperscript{207} Mobility of the shoulders and hips can change from game to game and cer-
tainly over the course of a season. Lee et al. reported that FMS performance declined during the competitive season compared to the preseason in high school baseball all players. In a randomized controlled trial, Suzuki et al. reported that high school baseball players can improve their FMS scores with individualized exercise programs but quickly regress if the program is not maintained throughout the season.

Certainly, traditional preseason screening approaches are limited in their ability to account for how the MSK system behaves over time. Baseball players require frequent risk factor appraisal and monitoring due to the high environmental demands of the sport. Mobility and strength can decline as the season progresses resulting in the emergence of injury risk factors which were not present during preseason testing. Thus, there is a need for a field expedient screening tool which can identify MSK impairments throughout the entire kinetic chain and can quickly be administered by the coach. Repeated sampling of MSK movement quality will allow for early detection of important physical limitations otherwise not captured by a solitary preseason screen. The screening information could be used as a determinate of progression or regression in physical function, thus allowing the coach to make specific adjustments to their players’ arm care protocols and minimize MSK pain, soreness, or injury during the season.
3.1 Introduction

Injuries to the shoulder and elbow are common among high school baseball pitchers. The incidence of experiencing elbow or shoulder pain in high school pitchers is 1.0 per 1000 AEs and 1.5 per 1000 AEs, respectively. The shoulder and elbow joint are exposed to tremendous stress during the throwing motion which is typically repeated hundreds of times during competition throughout the season. A number of risk factors, including ROM and strength limitations, high levels of throwing volume, and an increase in acute workload have been identified as contributing to increased arm soreness and time loss injuries. To combat these risk factors, researchers have focused on investigating compliance with pitch counts, number of rest days in between starts, managing yearly pitching volume, discouraging pitching showcases, and playing catcher as secondary position. As a result, arm care programs, which typically consist of upper extremity strengthening and stretching, core stability, and management of pitching volume have been suggested as necessary components of injury prevention plans for pitchers of all ages.

To reduce the risk of injury to the shoulder and elbow, the USA BMSAC and Major League Baseball established the Pitch Smart guidelines in 2014. These guidelines proposed age specific throwing limitations in an attempt to manage pitching volume, workload, and fatigue. However, understanding and compliance of these guidelines among baseball coaches have been underwhelming.

In a 2018 survey of 61 baseball
coaches, Knapik et al\textsuperscript{26} found that only 56\% of coaches kept track of pitch counts routinely and only 43\% reported compliance with age specific pitch count recommendations. Considering the poor compliance and knowledge relative to the Pitch Smart guidelines, it is reasonable to suggest that underutilization and lack of awareness regarding arm care programs could also be problematic. Knapik et al,\textsuperscript{26} reported that only 8\% of the 61 baseball coaches surveyed could correctly identify risk factors that could lead to overuse injury. This lack of knowledge of physical risk factors makes designing effective arm care programs difficult.

When implemented, arm care programs have been shown to be effective at reducing overuse injuries to the elbow and shoulder in overhead athletes.\textsuperscript{86,88,159,220} In a randomized controlled trial, Sakata et al\textsuperscript{86} demonstrated a 48.5\% reduction in elbow overuse injuries in youth baseball players. Shitara et al\textsuperscript{88} reported that stretching the posterior shoulder muscles lowered the incidence of shoulder and elbow injuries by 36\% in high school baseball pitchers. While these two studies showcase the potential effectiveness of arm care programs, there has been no investigation into high school baseball coaches’ current usage and perceptions of arm care programs to improve physical impairments associated with the injury risk factors described above.

To date, the authors are unaware of another study which has explored the application and characteristics of arm care programs from the perspective of the high school baseball coach. Therefore, the purpose of this study was to investigate if high school baseball coaches are using arm care programs to promote shoulder and elbow health for their players. The primary objective was to determine if high school baseball coaches are implementing generalized group-based programs or individualized arm care based on the
specific needs of the player. It was hypothesized that less than 50% of high school coaches who implement arm care exercises will use individualized programs. The secondary objective was to investigate if the use of arm care programs is influenced by coaches’ age, education, and experience level. It was hypothesized that older coaches with more education and experience will be more likely to implement individualized arm care exercises. Finally, this study explored potential barriers to arm care implementation and high school baseball coaches’ current awareness and beliefs associated with injury prevention. It was hypothesized that limited time and resources would be identified as common barriers to arm care implementation and that high school coaches would demonstrate limited knowledge of important injury risk factors.

3.2 Materials and Methods

3.2.1 Survey Development

This was a descriptive, cross-sectional study which evaluated the current application and characteristics of arm care programs and injury prevention concepts in high school baseball coaches. An electronic survey (Appendix 1) was developed in Qualtrics (electronic data capture tools hosted at the University of Kentucky) based on the current literature involving injury prevention exercise programs in adolescent baseball players. The survey was created by two rehabilitation professionals (KAM and TLU) with multiple years of clinical and research experience in baseball. The survey contained 29-items which were represented in three sections including, 1) demographics/coaching experience, 2) characteristics and application of arm care programs, and 3) knowledge and beliefs of injury prevention measures.
The first section consisted of five questions related to demographic information such as the participant’s age, education level, and coaching experience. Additional questions in this section were related to the age and competition level (school team, recreational league, or traveling team) of the baseball players the participant has coached. The second section had 17 questions which were designed to explore the application and characteristics of arm care programs among high school coaches. The questions in this section were specific to the design of arm care programs and examined the concepts of group versus individualized programs, goals, program components, frequency of performance per week, time allocated to specific exercises and body regions, and barriers to implementation. The third section had seven questions which were designed to determine the high school coaches’ knowledge and current beliefs related to injury prevention. The questions in this section asked about injury risk factors specific to baseball players, effectiveness of arm care programs related to injury incidence reduction, and whether or not risk factors should be monitored throughout the season.

Prior to nationwide distribution, the intra-rater reliability of the survey was assessed in a sample of 11 baseball coaches. Each coach completed the survey twice with a 10-day washout period in-between and absolute intra-rater agreement was measured with a weighted Cohen’s kappa statistic. The survey demonstrated excellent intra-rater absolute agreement with a weighted kappa value of 0.87 and excellent internal consistency with a Cronbach’s alpha of 0.97.221,222

3.2.2 Survey Sampling

Approximately 18,500 high school baseball coaches were contacted through email to participate in the online survey. Participant recruitment was conducted by the National
High School Baseball Coaches Association and through access to the Clell Wade Coaches Online Directory. Both organizations have directories containing email addresses of thousands of high school baseball coaches throughout the United States. These organizations directly contacted the participants though their email database and provided them with the link to the survey.

The investigators of this study did not have access to participants’ emails or any other personal identification information. Participation in the survey was voluntary and all responses to the survey were anonymous. Prior to beginning the survey, participants read the consent form and checked the “I agree” option if they wished to consent to the study. Participants were included in the study if they were willing and able to complete the online survey. Participants were excluded if they did not complete the required survey questions or selected the “I do not agree” to consent option prior to filling out the survey. Responses to the online survey were prospectively collected for three consecutive months from February to April 2020. Approvals from the institutional review boards at the University of Kentucky and the University of Evansville were obtained prior to data collection for this descriptive survey study.

3.2.3 Statistical Analysis

According to the National Federation of State High School Associations, there are approximately 20,000 high school baseball coaches in the United States. Therefore, a sample size of 377 participants was needed to ensure the responses reflected the views of the population with a 95% confidence interval and a 5% margin for error. Descriptive statistics for nominal and ordinal data were summarized through frequencies and percentages and analyzed for differences with a one-way chi-square test. Cross tabulations and
chi-square tests of independence were used to consider associations between use of arm care programs and coaching experience, age, and education level. An alpha level of $p<0.05$ was considered statistically significant for all tests. All data analyses were performed with SPSS statistical software (IBM SPSS Statistics for Mac, Version 26.0).

3.3 Results

A total of 688 (3.7%) high school baseball coaches throughout the United States responded to the online survey between February 3, 2020 and April 7, 2020. Of these 688 surveys, 34 were excluded due to insufficient completion of questions beyond the demographics section. Therefore, the remaining 654 surveys represented an inclusion rate of 96% (654/688) and were used for data analyses. Demographic information for the coaches’ age, years of coaching experience, educational level obtained, age of players coached, and level of players coached is displayed in Table 3.1.

3.3.1 Application and Characteristic of Arm Care Programs

In high school baseball coaches who responded to the survey, 87.3% (n=571/654) reported that they have their players perform an arm care program to maintain/improve upper extremity health (Table 3.2). Amongst the coaches who perform an arm care program, there were more coaches performing group-based programs (81.4%, n=465/571) than individualized arm care programs (18.6%, n=106/571) which were specific to the players’ needs ($p<0.001$) (Table 3.2). Overall, 85.2% (n=557/654) of coaches reported that they would be interested in an arm care screening tool to better inform their programs. Furthermore, 71.1% (n=59/83) of coaches who are not currently doing an arm care program would be interested in an arm care screening tool to guide their program ($p<0.001$).
Chi-Square analysis revealed no significant relationship between the age of the high school baseball coach and whether the coach chose to use an arm care program with their players \((p=0.325)\). However, coaches over the age of 40 years were significantly more likely to design individualized arm care programs for their players compared to group-based programs \((p=0.002)\). Coaches with greater than seven years of coaching experience were significantly more likely to use an arm care program \((p<0.001)\) and individualize the program to address the specific needs of their players \((p<0.001)\). There was no significant relationship between use of arm care programs and the coaches’ level of terminal degree achieved \((p=0.458)\). (Table 3.3)

3.3.2 Barriers to Implementation

The coaches who did not perform arm care programs identified the largest barrier reported was not seeing the benefit of an arm care program \((41\%, n=34/83)\) and not having enough staff to assist \((31.3\%, n=26/83)\). (Figure 3.1) Only 11% of 83 coaches reported that lack of time was a major barrier to implementing arm care exercises. Moreover, 96.6% \((n=552/571)\) of coaches allow the players to perform arm care during practice time. Sixty percent \((n=342/571)\) of coaches consider 10-20 minutes of practice time dedicated to arm care exercises reasonable and 36.8% \((n=205/571)\) encourage their players to perform their exercises 3x/week. (Table 3.2)

3.3.3 Injury Prevention Awareness and Beliefs

Most high school coaches \((64.1\%, n=366/571)\) who have their players perform arm care programs reported that the main goal for the program is prevention of injuries \((Figure 3.2)\). Among high school baseball coaches, 97.7% \((n=639/654)\) either “strongly
agree” or “agree” that injury risk factors should be monitored throughout the entire season (Table 3.4). However, when surveyed on which risk factors contributed most to pitching injuries, the majority of coaches reported that reduced shoulder ROM was the largest contributor (42.4%, n=277/651) followed by pitching > 8 months per year (33%, n=215/651). However, throwing with a fatigued arm and playing catcher as a secondary position were only identified as risk factors in 16.7% (n=109/651) and 2% (n= 12/654) of coaches surveyed, respectively (Fig 3.3). Furthermore, 27.7% of 654 surveyed coaches were either “not sure” or “disagreed” that a previous injury increases risk for future injuries.

Overall, 98.3% (n=643/654) of high school baseball coaches believe that arm care programs can reduce throwing-related upper extremity injuries (Table 3.4). Furthermore, 57.3% (n=375/654) of high school baseball coaches reported that the coaches play the largest role in preventing baseball injuries. Interestingly, coaches believed that parents and medical professionals such as physical therapists, athletic trainers, and physicians play a much smaller role in preventing baseball injuries. Only 2.8% (n=18/654) of high school coaches believed that parents played the greatest role in injury prevention, whereas only 1.5% (n=10/654) of coaches believed that medical professionals were responsible. (Figure 3.4)

3.4 Discussion

The overarching purpose of this survey was to investigate the usage of arm care programs by high school baseball coaches to promote arm health. The results of the survey demonstrated greater than 87% of responding high school coaches implement arm
care programs. From the perspective of the coach, the primary objective for arm care programming is to prevent injuries, but the results suggest that their injury prevention awareness and strategies are limited. The notion that arm care exercise programs can reduce injury incidence is not a novel concept as several prior studies have supported this outcome.\(^{40,86,88}\) Specifically, multi-modal arm care programming has been shown to reduce the incidence of medial elbow injuries in youth baseball players by nearly 50\%.\(^{40,86}\) However, to the authors’ knowledge this is the first survey which has explored arm care and injury prevention from the perspective of the high school coach. Although 13\% of coaches do not currently implement an arm care program, 71\% (n=59/83) of those coaches are interested in using a screening tool to aid in designing a program. The primary objective of this survey was to determine if coaches use group-based or individualized arm care programs. It also sought to explore how the coaches’ age, education, and experience level influenced the type of arm care programs implemented. The majority of high school baseball coaches who responded to this survey reported using group-based arm care programs. This is not surprising as the only arm care programs which have been explored in the current literature are group-based programs.\(^{40,86,88}\) Older and more experienced coaches tended to implement individualized arm care programs more so than younger coaches with less coaching experience. One possible explanation for this relationship could be that longer tenured coaches may have observed better player durability with individualized arm care programming. This may be due to the variability of different combinations of risk factors among individuals such as body mass index, biomechanics, or muscle flexibility.\(^{175}\) Furthermore, increasing the dosage of exercises designed to target a specific risk factor may maximize the outcome.\(^{175}\) To date there have
been no studies which have evaluated individualized arm care programs in baseball players. However, in high school soccer players, Huebner et al.\textsuperscript{175} reported that an individualized injury prevention program significantly lowered the injury risk in 21 out of 44 players. Baseball players may also benefit from individualized arm care exercises, but future research is needed to determine if targeting risk factors specific to the individual is more effective than group programming in this population.

The secondary purpose of this survey was designed to identify barriers that discouraged coaches from implementing arm care programs for their players. It was hypothesized that lack of time would be a major barrier to implementation, but only 11% (n=9/83) of responding coaches identified this as a limitation. Interestingly, 41% of 83 respondents not using arm care programs reported lack of benefit of the program as the primary reason. This is somewhat a paradoxical perspective as 98.3% of all coaches surveyed also agreed that arm care programs can reduce shoulder/elbow injuries. It is possible that coaches have been taught that arm care exercises can reduce injuries but are hesitant to buy in to program implementation because of a lack of observed effectiveness.

The second most frequently cited barrier to arm care implementation reported by coaches surveyed was insufficient staff. This is not surprising as additional support staff in high school programs are typically limited due to marginalized budgets.\textsuperscript{224,225} However, researchers have shown that arm care exercises can reduce injury incidence in adolescent baseball players without additional staff or equipment. In a prospective cohort, Shitara et al.\textsuperscript{88} reported a 36% reduction in upper extremity injury incidence in high school baseball players who performed posterior shoulder stretching. Likewise, Sakata et al.\textsuperscript{86} found that a 10-minute warm up program that targeted multiple physical risk factors
reduced the incidence of medial elbow pain by nearly 50% in youth baseball players.

Neither program by Shitara et al\textsuperscript{88} or Sakata et al\textsuperscript{86} required additional equipment and was performed independently by the players.

Finally, this survey explored high school baseball coaches’ current awareness and beliefs of injury prevention. The responding high school coaches demonstrated variability in knowledge of risk factors and injury prevention measures. Whereas many coaches acknowledged that dysfunction in hips and core can contribute to throwing related injuries, only 25% of coaches strongly agreed that previous injury can lead to a future injury. Research has suggested that a history of a previous injury is one of the strongest and most consistently reported risk factors for future injury.\textsuperscript{67,113,170,226} Also, reduced shoulder ROM was selected by high school coaches as the risk factor contributing the most to injury. Multiple studies have reported that limited shoulder ROM can contribute to increased injury in high school and professional baseball players. Specifically, Shanley et al\textsuperscript{46} reported that high school baseball players with $\geq 25^\circ$ GIRD were 4.8 times greater risk of having an upper extremity injury. Shitara et al\textsuperscript{88} reported that a 20° GIRD was associated with 2.7 times greater odds for injury. In professional players, total shoulder range of motion differences of greater than 5° have been significantly related to injury incidence.\textsuperscript{102} Although the responding coaches were able to successfully identify reduced shoulder ROM as a risk factor, it is concerning that far fewer coaches considered increased pitching volume as a major concern for arm injury.

In the current survey, only 17% (n=109/654) of respondents identified throwing with a fatigued arm as the primary injury risk factor. It was expected that pitching with arm fatigue would be identified as the greatest risk factor due to literature showing that
throwing with a fatigued arm increases the odds of upper extremity injury 13-fold (95% CI, 3.22 to 55.09).\textsuperscript{227} Throwing for greater than eight months of the year which has been shown to increase injury risk five-fold was identified as the primary risk factor in 33% of respondents. Hibberd et al\textsuperscript{215} reported that pitchers who also play catcher as a secondary position are nearly three times greater risk for injury but only 2% (n=12/654) of responding coaches identified this a primary risk factor. Researchers have shown that loss of shoulder strength during season may play a role in arm injury in baseball players. A study performed by Tyler et al\textsuperscript{47} on a sample of high school baseball players reported that preseason supraspinatus weakness increased the risk of having substantial injury resulting in missing greater than three games by four-fold (RR=4.6; 95% CI, 1.4 to 15.0). However, despite this research, only 6% (n=38/654) of high school coaches ranked strength as the major contributor to injury. The coaches tended to focus on motion deficits of the shoulder perhaps because of the long-standing nature of this information but inconsistently reported throwing volume a major factor. This suggests that coaches may require updated education related to injury risk factors.

The results of those surveyed indicate that the majority of high school coaches accept the primary role of preventing baseball injuries. High school coaches believe that they can positively impact the health and well-being of their players more effectively than healthcare providers despite their poor knowledge of injury risk factors. In conjunction with the majority of coaches using arm care programs, it appears that time is not a limiting factor. In fact, responding coaches dedicate 10-20 minutes of practice time three times per week to arm care exercises. However, coaches and rehabilitation professionals could do a better job collaborating on risk factors and injury prevention strategies. Future
research is needed to gain insight into the resources commonly used by coaches for injury prevention information. It is unlikely high school baseball coaches are aware of this medical literature which may explain why there is a disconnect between current medical literature and knowledge among high school coaches. This may make it difficult for high school coaches to implement and design effective arm care programs for their players. Collaborative efforts between rehabilitation professionals and coaches are needed to provide educational opportunities for injury prevention strategies. This may include providing up to date information in a location which is easily assessable and practically applicable for the coaches’ everyday needs.

3.5 Limitations

This study is not without limitations. First, the survey data were based on self-report which may have resulted in reporting bias by the responding coaches. Because the majority of responders were more positive in arm care program use, the coaches surveyed were likely biased toward this value. Additionally, the nature of the survey design cannot confirm actual practice, therefore, the results of the coaches’ injury prevention knowledge could be skewed. Second, the authors used email to attempt to survey a geographically diverse sample of high school coaches throughout the United States. However, technologic restrictions such as limited access to a computer or internet may have resulted in a selection bias. Lastly, while this survey did report on the usage of arm care programs, it did not specifically inquire about how effective the coaches perceived these programs are at preventing injury.
3.6 Conclusions

The results of this survey suggest that the majority of high school baseball coaches implement group-based arm care exercise programs to prevent injury. Coaches who were older and more experienced were more likely to individualize their arm care programs. Lack of time is not a major barrier to implementation of arm care programming. High school coaches believe they are the most impactful at preventing baseball injuries and devote practice time multiple days per week to arm care exercises. However, the responding coaches exhibited inconsistent risk factor awareness and dated injury prevention beliefs. Therefore, better educational collaboration between rehabilitation professionals and high school coaches regarding injury risk factors and preventative strategies is warranted.
Table 3.1 Demographics of High School Coaches

<table>
<thead>
<tr>
<th>Question</th>
<th>n</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>How old are you?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20 years</td>
<td>0</td>
<td>(0)</td>
</tr>
<tr>
<td>20-29 years</td>
<td>77</td>
<td>(11.8)</td>
</tr>
<tr>
<td>30-39 years</td>
<td>190</td>
<td>(29.1)</td>
</tr>
<tr>
<td>40-49 years</td>
<td>205</td>
<td>(31.3)</td>
</tr>
<tr>
<td>&gt;50 years</td>
<td>182</td>
<td>(27.8)</td>
</tr>
<tr>
<td>What level of team do you coach?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreational team</td>
<td>25</td>
<td>(13.5)</td>
</tr>
<tr>
<td>School team</td>
<td>619</td>
<td>(84.9)</td>
</tr>
<tr>
<td>Traveling team</td>
<td>5</td>
<td>(0.8 )</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>(0.8 )</td>
</tr>
<tr>
<td>What is the age of the baseball players you coach?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;15 years</td>
<td>13</td>
<td>(2.0 )</td>
</tr>
<tr>
<td>15-18 years</td>
<td>636</td>
<td>(97.4)</td>
</tr>
<tr>
<td>19-22 years</td>
<td>4</td>
<td>(0.4 )</td>
</tr>
<tr>
<td>&gt;22 years</td>
<td>1</td>
<td>(0.2 )</td>
</tr>
<tr>
<td>How many years have you been involved in coaching baseball?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1 year</td>
<td>5</td>
<td>(0.8 )</td>
</tr>
<tr>
<td>1-3 years</td>
<td>33</td>
<td>(5.0 )</td>
</tr>
<tr>
<td>4-6 years</td>
<td>80</td>
<td>(12.2)</td>
</tr>
<tr>
<td>7-10 years</td>
<td>95</td>
<td>(14.5)</td>
</tr>
<tr>
<td>&gt;10 years</td>
<td>441</td>
<td>(67.5)</td>
</tr>
<tr>
<td>What is the highest education level you have achieved?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school/GED</td>
<td>7</td>
<td>(1.1 )</td>
</tr>
<tr>
<td>Some college</td>
<td>0</td>
<td>(0)</td>
</tr>
<tr>
<td>Bachelor of Science</td>
<td>265</td>
<td>(40.5)</td>
</tr>
<tr>
<td>Master’s degree</td>
<td>303</td>
<td>(46.3)</td>
</tr>
<tr>
<td>Doctoral degree</td>
<td>22</td>
<td>(3.4 )</td>
</tr>
</tbody>
</table>
Table 3.2  Arm Care Application and Characteristics

<table>
<thead>
<tr>
<th>Question</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you currently have your players perform a program to improve arm health?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>571 (87.3)</td>
</tr>
<tr>
<td>No</td>
<td>83 (12.7)</td>
</tr>
<tr>
<td>Which of the following best describes your arm care program?</td>
<td></td>
</tr>
<tr>
<td>Group-based - general program that is similar to all players</td>
<td>465 (81.4)</td>
</tr>
<tr>
<td>Individualized - each player receives different exercises specific to their needs</td>
<td>106 (18.5)</td>
</tr>
<tr>
<td>Would you be interested in a 3-minute screen to help individualize your arm care program?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>557 (85.2)</td>
</tr>
<tr>
<td>No</td>
<td>97 (14.8)</td>
</tr>
<tr>
<td>Should pitchers participate in an exercise program to improve/maintain arm health?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>570 (99.8)</td>
</tr>
<tr>
<td>No</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td>Do your players perform the arm care program during baseball practice time?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>552 (96.6)</td>
</tr>
<tr>
<td>No</td>
<td>19 (3.4)</td>
</tr>
<tr>
<td>How many times per week do your players perform your arm care program during the season?</td>
<td></td>
</tr>
<tr>
<td>1x/week</td>
<td>9 (1.6)</td>
</tr>
<tr>
<td>2x/week</td>
<td>79 (14.2)</td>
</tr>
<tr>
<td>3x/week</td>
<td>205 (36.8)</td>
</tr>
<tr>
<td>4x/week</td>
<td>51 (9.2)</td>
</tr>
<tr>
<td>5x/week</td>
<td>107 (19.2)</td>
</tr>
<tr>
<td>6x/week</td>
<td>96 (17.2)</td>
</tr>
<tr>
<td>7x/week</td>
<td>10 (1.8)</td>
</tr>
<tr>
<td>What time of year do you have your players perform your arm care program?</td>
<td></td>
</tr>
<tr>
<td>Preseason only</td>
<td>7 (1.2)</td>
</tr>
<tr>
<td>Offseason only</td>
<td>19 (1.8)</td>
</tr>
<tr>
<td>Start of season to end of season</td>
<td>40 (7)</td>
</tr>
<tr>
<td>Preseason to end of season</td>
<td>337 (59)</td>
</tr>
<tr>
<td>Year around</td>
<td>177 (31)</td>
</tr>
</tbody>
</table>
Table 3.3 Comparison Between Coaches Demographics and Arm Care Programs

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the age of the coach associated with use of arm care programs?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;40 years</td>
<td>85.8%</td>
<td>14.2%</td>
<td>0.325</td>
</tr>
<tr>
<td>&gt;40 years</td>
<td>88.4%</td>
<td>11.6%</td>
<td></td>
</tr>
<tr>
<td>Is age associated with use of group vs. individualized arm care program</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;40 years</td>
<td>88.2%</td>
<td>11.8%</td>
<td>0.001</td>
</tr>
<tr>
<td>&gt;40 years</td>
<td>76.9%</td>
<td>23.1%</td>
<td></td>
</tr>
<tr>
<td>Is coaching experience associated with use of arm care programs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-6 years of experience</td>
<td>Yes 72.9%</td>
<td>No 27.1%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&gt;7 years of experience</td>
<td>Yes 90.5%</td>
<td>No 9.5%</td>
<td></td>
</tr>
<tr>
<td>Is coaching experience related to use of group or individualized arm care?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-6 years of experience</td>
<td>Group 88.4%</td>
<td>Individual 11.6%</td>
<td>0.043</td>
</tr>
<tr>
<td>&gt;7 years of experience</td>
<td>Group 80.2%</td>
<td>Individual 19.8%</td>
<td></td>
</tr>
<tr>
<td>Is education level related to use of arm care programming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No college degree</td>
<td>Yes 84.4%</td>
<td>No 15.6%</td>
<td>0.458</td>
</tr>
<tr>
<td>College degree</td>
<td>12.4%</td>
<td>87.6%</td>
<td></td>
</tr>
<tr>
<td>Is education level related to use of group or individualized arm care</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No college degree</td>
<td>Group 77.8%</td>
<td>Individual 22.2%</td>
<td>0.467</td>
</tr>
<tr>
<td>College degree</td>
<td>81.8%</td>
<td>18.2%</td>
<td></td>
</tr>
</tbody>
</table>

Yes=coach utilized arm care program  No=coach did not use arm care program
<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>A</th>
<th>NS</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm care programs can reduce elbow/shoulder injuries in baseball pitchers</td>
<td>68%</td>
<td>31%</td>
<td>1.7%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Having a previous injury will lead to an increased risk for a future injury?</td>
<td>25%</td>
<td>48%</td>
<td>19%</td>
<td>9%</td>
<td>0%</td>
</tr>
<tr>
<td>Deficits in hips or core can contribute to injuries of the shoulder or elbow?</td>
<td>45%</td>
<td>42%</td>
<td>13%</td>
<td>0.5%</td>
<td>0%</td>
</tr>
<tr>
<td>Injury risk factors should be monitored throughout the entire season?</td>
<td>71%</td>
<td>27%</td>
<td>2%</td>
<td>0.3%</td>
<td>0%</td>
</tr>
</tbody>
</table>

SA = strongly agree, A = agree, NS = not sure, D= disagree, SD = strongly disagree
Figure 3.1 Coaches’ ranking of greatest barriers to arm care implementation
Figure 3.2  Coaches’ response to primary goal of arm care programs
Figure 3.3  Coaches’ ranking of risk factors contributing most to pitching injuries
Figure 3.4 Coaches’ response to who has the greatest role in preventing injuries
CHAPTER 4. THE INTRA- AND INTER-RATER RELIABILITY OF AN ARM CARE SCREENING TOOL IN HIGH SCHOOL BASEBALL COACHES

4.1 Introduction

Baseball players are susceptible to shoulder and elbow injuries related to microtrauma from repetitive physical misuse of the kinetic chain.\textsuperscript{41,228} The overhead throwing motion, common in baseball, requires contribution of the entire body, specifically the hips, torso, and shoulder girdle.\textsuperscript{228} Limitations in any of these body regions can result in large amounts of mechanical stress placed on the upper extremity.\textsuperscript{33,41} Despite well-established pitching volume guidelines, injury rates in high school baseball players have not declined.\textsuperscript{5} Over the past two decades, elbow injuries, specifically UCL reconstruction, has become more frequent in adolescents and is expected to continue to rise.\textsuperscript{21,66} As a result, greater attention to identification and management of intrinsic modifiable risk factors such as strength, flexibility, and neuromuscular control is warranted for more comprehensive injury management.\textsuperscript{43}

Preseason examinations have identified modifiable risk factors associated with increased injury rates during the season.\textsuperscript{60,208} Movement screening can provide useful information specific to deterioration of function and potential for injury. Two movement examination tools that exist are the FMS and the SFMA which are designed to identify major limitations and/or asymmetries which could contribute to musculoskeletal pain or movement deficits.\textsuperscript{178,179,229} In high school baseball players, Lee et al\textsuperscript{189} reported that FMS composite scores and individual test performance declined over the course of the season. Most studies have focused on singular risk factors in common body regions while overlooking the presence of additional impairments throughout the kinetic chain.\textsuperscript{189} In collegiate baseball players, Busch et al\textsuperscript{84} reported that poor FMS and SFMA shoulder
mobility patterns were associated with five and six-fold greater odds of having an overuse injury during preseason training, respectively. However, Busch et al limited screening to only upper quarter tests and failed to include additional lower quarter movement patterns which would be more representative of the entire kinetic chain.

In most circumstances, high school coaches have limited resources needed to perform frequent movement screenings on their players. External factors such as funding for training, time constraints, and insufficient staffing limit implementation of injury screening. Specifically, the FMS requires testing equipment, multiple hours of training for certification, and takes approximately 10-15 minutes to perform on each player. The SFMA is a clinical assessment designed for practitioners with a license to diagnose and treat pain and therefore is out of the scope of practice for the coach. Thus, there is a need for a field expedient screening tool which can measure physical function throughout the kinetic chain that can quickly be administered by coaches. Frequent screening throughout the season could identify impairments and inform arm care training programs to improve strength and flexibility.

To date there are no studies which have explored a field expedient screening tool that can be quickly performed by high school baseball coaches. The purpose of this study was to establish the intra-rater and inter-rater reliability of a novel arm care screening tool based on the concepts of the FMS and SFMA in high school coaches. It was hypothesized that the ACS will demonstrate moderate intra-rater and inter-rater reliability with a Cohen's kappa value >0.40 when administered by high school baseball coaches.
4.2 Materials and Methods

4.2.1 Study Design

A prospective methodological cohort design was used to establish the intra-rater and inter-rater reliability of the ACS among high school baseball coaches. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement was followed for standardized reporting. Approval was granted from the institutional review board at the University of Kentucky and informed consent and assent forms were obtained prior to data collection.

4.2.2 Participants

A minimum sample size of 24 players was needed to achieve a Cohen’s kappa value of 0.40 with an alpha of 0.05 and 80% power for a two tailed test. Anticipating 10% of the participants would have missing or incomplete data the planned target sample size was 27 participants. A convenience sample of 31 male high school baseball players from a single local team volunteered to participate in this study. The head coach allowed the researchers to attend team workouts to recruit and test the players. Inclusion criteria required the participant to be a current and active member of a men’s varsity, junior varsity, or freshman high school baseball team. Exclusion criteria included the inability to participate in sport due to current injury, recent surgery (within three months), physician restriction, recent concussion (within one month) or vestibular issue. Players who are under the age of 14 or older than 18 were excluded (Figure 4.1).

4.2.3 Procedures

Data collection occurred over a four-week period in the fall offseason during team workouts. Physical testing occurred during a single session at the participants’ local high
school baseball field. Participants completed a demographic questionnaire which included information about their age, height, weight, playing position, baseball experience, and current injury status. All participants were scored once on ACS performance in real-time while being videotaped which would be reviewed later for intra-rater reliability.

The ACS is a modified movement-based screening tool which utilizes components of the FMS, SFMA, and YBT-LQ developed to improve field expediency and reduce scoring complexity. The ACS consists of three screens including, 1) reciprocal shoulder mobility, 2) 90/90 total body rotation, and 3) lower body (LB) diagonal reach (Figure 4.2). Each component of the ACS was scored as pass or fail on both the right and left sides. Pain with testing was recorded but did not factor into the scoring criteria. For full description and illustrations on ACS testing procedures and scoring see Appendix 8 of this dissertation.

*Reciprocal Shoulder Mobility:* The participant began in standing with feet together and both hands open. The participant simultaneously reached one hand behind their head and other hand behind and up their back, similar to an Apley’s Scratch test position, assuming an extended and internally rotated position with one shoulder and a flexed and externally rotated position with the other. The arms should move in one smooth motion and tall posture should be maintained while the participant attempts to touch the fingertips of both hands together. In order to pass this test the athlete much touch fingers tips when reaching in both directions. Inability to touch right and left fingertips together in both reach directions was considered a failure on the test.

*90/90 Total Body Rotation:* The participant assumes a standing position with feet together, toes pointing forward and arms in the 90/90 position (90° shoulder abduction and
90° elbow flexion). The participant rotated their entire body including the hips, shoulders, and head as far as possible to the right while the foot position remained unchanged. Inability to see the back shoulder when viewed from behind on both sides was considered failure on the test.

*Lower Body Diagonal Reach:* The participant stood two shoe lengths away from a wall and while maintaining single leg balance on one foot the participant reaches with the opposite foot behind and across their body to touch the wall where it meets the ground, then return to start position without touching the reach foot to the ground. To pass this test the athlete must repeat this maneuver five consecutive times without the reach foot touching down or losing balance. The test is repeated while standing on the opposite leg. Inability to touch the wall five consecutive times or loss of balance on either side was considered failure on the test.

### 4.2.4 Intra-rater and Inter-rater Reliability

Two high school baseball coaches were recruited to score the ACS at two different time points. Prior to data collection, both coaches signed the informed consent and underwent a 1-hour electronic ACS training session performed by the lead author (KAM). Following the training session, both coaches were required to pass an online ACS competency examination with a score of ≥ 80% prior to data collection. Additional online training and a retake exam would be provided for coaches scoring < 80% on the exam. Remediation was not required in this study since both coaches passed their exam on the first attempt.

The participants were given the ACS instructions by one rater (KAM) while the testing was observed by two other raters (TO and JB) simultaneously in real-time. All
raters were blinded to each other’s scoring. The PT rater (KAM) was a physical therapist with 10 years of experience working with baseball players and coach rater 1 (C1) (JB) and coach rater 2 (C2) (TO) were assistant high school baseball coaches with >5 years of coaching experience. Concurrently, all participants were video recorded performing the ACS testing procedures during the live testing. An iPhone 10XR cell phone was placed approximately 15 feet directly posterior to the participant. Following a 7-day washout period, the same three raters rescoring the ACS performance electronically from the video recordings taken during the live testing and were blinded to each other's results. To minimize recall bias, the order of the videos was randomized to differ from the original live testing order.

4.2.5 Statistical Analysis

Descriptive statistics including means and standard deviations (SD) or frequency counts were calculated as appropriate. Intra-rater and inter-rater reliability for the categorical scores of each component of the ACS were compared within and between (PT to C1, PT to C2, and C1 to C2) each rater using Cohen’s kappa coefficient with 95% confidence intervals and percent absolute agreement. The Cohen’s kappa coefficient quantifies the strength of agreement and was interpreted as: ≤ 0.40 = poor to slight, 0.41-0.60 = moderate, 0.61-0.80 = substantial, ≥ 0.80 = excellent.233 All data analyses were performed with SPSS statistical software (IBM SPSS Statistics for Mac, Version 27.0). An alpha level of $p < 0.05$ was considered statistically significant for all tests.

4.3 Results

Demographic characteristics of all participants are provided in Table 4.1. The mean age ± SD of the participants in this sample was $15.9 \pm 1.06$, 45.2% (n=14/31) were
high school sophomores, and 25.8% (n=8/31) were primarily pitchers. A total of 29% (n=9/31) of participants reported pain with at least one component of the ACS. All 31 participants completed the testing procedures, and the results were used for data analysis.

4.3.1 Intra-rater and Inter-rater Reliability

Results of intra-rater reliability scores after a seven-day washout period within all three raters are presented in Table 4.2 with corresponding Cohen’s kappa values with 95% confidence intervals and percent agreement. Cohen’s kappa values for the three component tests of the ACS (scored pass or fail) demonstrated moderate to excellent intra-rater agreement. The mean intra-rater reliability for all raters was substantial with a Cohen’s kappa value of 0.76 (95% CI, 0.54-0.95) and a mean absolute agreement was 89%. The PT rater demonstrated higher intra-rater reliability compared to C1 and C2, but these differences were not statistically significant ($p > 0.05$).

The results for ACS same day inter-rater reliability with Cohen’s kappa values, 95% confidence intervals, and percent absolute agreement are presented in Table 4.3. Cohen kappa values ranged from substantial to excellent agreement between all three raters depending on the specific movement component of the ACS. The mean inter-rater reliability for all raters was excellent with a Cohen’s kappa value of 0.89 (95% CI, 0.77-0.99) and a mean absolute agreement was 95%. The overall mean kappa agreement when comparing each raters’ performance on all ACS components demonstrated near perfect agreement and did not differ significantly between raters ($p > 0.05$).

4.4 Discussion

The purpose of this study was to establish the intra- and inter-rater reliability of a field expedient arm care screening tool in a sample of high school players. The findings
from this study supports the primary hypothesis that baseball coaches can reliably administer the ACS to screen high school players. All three components of the ACS, scored as pass or fail, exhibited substantial to excellent intra- and inter-rater reliability among all three raters regardless of their coaching or movement screening experience.

The reliability of movement-based screening tools has been evaluated in multiple populations among raters of differing professional backgrounds such as physical therapists, certified athletic trainers (ATC), and strength and conditioning specialists.\textsuperscript{2,10,35} The results of the current study are similar to previous literature investigating rater agreement of the FMS and SFMA. Mininck et al\textsuperscript{34} reported substantial to excellent inter-rater reliability ($k_w = 0.74-1.0$) among expert FMS raters and novice raters while scoring FMS performance from video recordings. Likewise, Teyhen et al\textsuperscript{57} reported moderate to excellent inter-rater and test-retest agreement in physical therapy students on the component tests of the FMS when scored in real time. Moderate intra-rater (ICC = 0.75; 95% CI, 0.53-0.87) reliability has been observed among ATCs and athletic training students when evaluating the composite score of the FMS in real time.\textsuperscript{19} Conversely, Shultz et al\textsuperscript{234} which included strength and conditioning coaches, showed fair to poor inter-rater reliability ($k = 0.38; 95\% \text{ CI } 0.35-0.41$) of FMS subsets.

The SFMA categorical scoring criteria have demonstrated slight to substantial intra-rater ($k=0.48-0.83$) and inter-rater ($k=0.20-0.76$) reliability in healthy adults.\textsuperscript{13,17,56} However, reliability conclusions are limited to only physical therapists and ATCs to date. To the authors’ knowledge this is the first study to specifically examine the ability of high school baseball coaches to screen movement patterns accurately and consistently. Previously, three studies exploring the reliability of the SFMA used video analysis to aid
The methodology of the current study included both real-time scoring and video analysis to establish reliability of the ACS. Although video analysis was consistent with previous SFMA reliability studies, the utility of the ACS is more applicable to coaches when scoring players in real-time during practice which warranted exploration of live screening accuracy.

Previous research has reported that raters with more movement screening experience have better intra-rater and inter-rater reliability compared to less experienced raters. In the current study, there was no reliability differences between raters even though the PT rater had 10 years of experience screening movement while C1 and C2 only had a 1-hour educational session prior to data collection. It is likely that the reduced number of categorical scoring options compared to other movement screens minimized errors among the raters. By dichotomizing each component of the ACS as pass or fail, scoring complexity is reduced and the raters are better able to agree on the testing results regardless of their experience.

Resources, experience, and staffing limitations prevent high school coaches from performing comprehensive musculoskeletal assessments and testing on their players multiple times during the season. The ACS provides coaches with a tool to track changes in movement quality and decreased physical function so that exercise intervention can be recommended prior to the onset of injury. High school coaches can perform the ACS in less than three minutes which is more time efficient and feasible compared to the 10-15 minutes needed to administer the FMS. Furthermore, minimal training (~1 hour) is required to be proficient in scoring the ACS with no additional costs or certification required to implement. While the ACS has shown to be reliable, validation of the screening
tool is warranted prior to mainstream use in high school athletics. Future research should investigate the discriminability of the ACS to detect musculoskeletal impairments and risk factors in baseball players.

4.5 Limitations

The authors acknowledge that this study is not without limitations. First, external validity of the intra-rater reliability may have been affected by performing live screens initially but rescreening seven days after from a video recording. During live screening the raters where able to view the participants movement from multiple different angles as opposed to only a singular posterior view on the video recording. Despite the different scoring approaches, Cohen’s kappa values were not drastically affected as intra-rater reliability was excellent among all raters. Secondly, the current study focused specifically on high school baseball players who played a variety of positions. The results of this study may not be generalizable to baseball players at the professional and collegiate level. We included only high school players to maximize homogeneity of our sample, however, we also included both position players and pitchers. Musculoskeletal function differs between pitchers and position players and likely resulted in increased heterogeneity among our participants.

4.6 Conclusions

High school baseball coaches with limited experience screening movement can reliably score all three components of the ACS in less than three minutes with minimal training. All raters demonstrated substantial to excellent intra- and inter-rater reliability which did not differ based on screening experience. Therefore, the ACS is a highly feasi-
ble movement screening option for implementation in the high school baseball environment. Future research should focus on exploring the discriminant validity of the ACS at identifying MSK impairments and injury risk factors.
Table 4.1 Descriptive Characteristics of High School Baseball Players  
(n=31)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>15.9 ± 1.06</td>
</tr>
<tr>
<td>Height, cm</td>
<td>178.9 ± 6.6</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>72.2 ± 10.3</td>
</tr>
<tr>
<td>Dominant limb, n (%)</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>27 (87.1)</td>
</tr>
<tr>
<td>Left</td>
<td>4 (12.9)</td>
</tr>
<tr>
<td>Years of Baseball Experience</td>
<td>10.2 ± 2.65</td>
</tr>
<tr>
<td>Year in School, n (%)</td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>5 (16.1)</td>
</tr>
<tr>
<td>Sophomore</td>
<td>14 (45.2)</td>
</tr>
<tr>
<td>Junior</td>
<td>7 (22.6)</td>
</tr>
<tr>
<td>Senior</td>
<td>5 (16.1)</td>
</tr>
<tr>
<td>Primary Position, n (%)</td>
<td></td>
</tr>
<tr>
<td>Pitcher</td>
<td>8 (25.8)</td>
</tr>
<tr>
<td>Catcher</td>
<td>1 (3.2)</td>
</tr>
<tr>
<td>Infield Player</td>
<td>12 (38.7)</td>
</tr>
<tr>
<td>Outfield Player</td>
<td>10 (32.3)</td>
</tr>
</tbody>
</table>

*SD=standard deviation, y=year
Table 4.2 Intra-rater Reliability of ACS Components (n=31)

<table>
<thead>
<tr>
<th></th>
<th>PT Rater</th>
<th>C1 Rater</th>
<th>C2 Rater</th>
<th>Mean of all Raters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kappa (95% CI)</td>
<td>% Agree</td>
<td>Kappa (95% CI)</td>
<td>% Agree</td>
</tr>
<tr>
<td>Nondominant Shoulder Mobility</td>
<td>0.81 (0.60-1.0)</td>
<td>0.90</td>
<td>0.62 (0.36-0.87)</td>
<td>0.81</td>
</tr>
<tr>
<td>Dominant Shoulder Mobility</td>
<td>1.0 (1.0-1.0)</td>
<td>1.00</td>
<td>0.78 (0.56-1.0)</td>
<td>0.90</td>
</tr>
<tr>
<td>Nondominant Total Body Rotation</td>
<td>0.80 (0.59-1.0)</td>
<td>0.90</td>
<td>0.74 (0.49-0.98)</td>
<td>0.87</td>
</tr>
<tr>
<td>Dominant Total Body Rotation</td>
<td>0.83 (0.61-1.0)</td>
<td>0.94</td>
<td>0.74 (0.46-1.0)</td>
<td>0.90</td>
</tr>
<tr>
<td>Stride LB Diagonal Reach</td>
<td>0.60 (0.32-0.87)</td>
<td>0.81</td>
<td>0.87 (0.70-0.78)</td>
<td>0.94</td>
</tr>
<tr>
<td>Stance LB Diagonal Reach</td>
<td>0.68 (0.43-0.93)</td>
<td>0.84</td>
<td>0.50 (0.22-0.83)</td>
<td>0.74</td>
</tr>
</tbody>
</table>

| Mean | 0.79 (0.59-0.97) | 0.90 | 0.71 (0.47-0.91) | 0.86 | 0.78 (0.57-0.97) | 0.90 | 0.76 (0.54-0.95) | 0.89 |

*Nondominant=nondominant arm, Dominant=dominant arm, LB=lower body, CI=95% confidence interval
Table 4.3  Inter-rater Reliability of ACS Components  
(n=31)

<table>
<thead>
<tr>
<th></th>
<th>PT Rater vs. C1 Rater</th>
<th>PT Rater vs. C2 Rater</th>
<th>C1 Rater vs. C2 Rater</th>
<th>Mean of all Raters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kappa (95% CI)</td>
<td>% Agree</td>
<td>Kappa (95% CI)</td>
<td>% Agree</td>
</tr>
<tr>
<td>Nondominant Shoulder Mobility</td>
<td>1.0 (1.0-1.0)</td>
<td>1.00</td>
<td>1.0 (1.0-1.0)</td>
<td>1.00</td>
</tr>
<tr>
<td>Dominant Shoulder Mobility</td>
<td>0.92 (0.76-1.0)</td>
<td>0.97</td>
<td>0.92 (0.76-1.0)</td>
<td>0.97</td>
</tr>
<tr>
<td>Nondominant Total Body Rotation</td>
<td>0.73 (0.48-0.97)</td>
<td>0.87</td>
<td>0.86 (0.67-1.0)</td>
<td>0.93</td>
</tr>
<tr>
<td>Dominant Total Body Rotation</td>
<td>0.91 (0.74-1.0)</td>
<td>0.97</td>
<td>0.91 (0.75-1.0)</td>
<td>0.97</td>
</tr>
<tr>
<td>Stride LB Diagonal Reach</td>
<td>0.81 (0.60-1.0)</td>
<td>0.93</td>
<td>0.67 (0.41-0.93)</td>
<td>0.84</td>
</tr>
<tr>
<td>Stance LB Diagonal Reach</td>
<td>0.94 (0.81-1.0)</td>
<td>0.97</td>
<td>0.87 (0.70-1.0)</td>
<td>0.94</td>
</tr>
<tr>
<td>Mean</td>
<td>0.88 (0.73-0.99)</td>
<td>0.95</td>
<td>0.87 (0.72-0.99)</td>
<td>0.94</td>
</tr>
</tbody>
</table>

*Nondominant=nondominant arm, Dominant=dominant arm, LB=lower body, CI=95% confidence interval
Enrollment

- Approached for recruitment (n = 40 players, 4 coaches)
  - Excluded (n = 9 players, 2 coaches)
    - Outside of age criteria (n = 2 players)
    - Declined participation (n = 7 players, 2 coaches)

Data Collection

- Participated in Data Collection (n = 31 players, 2 coaches)

Follow up

- Lost to follow-up (n = 0 players, 0 coaches)

Analysis

- Analyzed (n = 31 players, 2 coaches)

Figure 4.1 CONSORT flow diagram
Figure 4.2  Arm Care Screen
CHAPTER 5. A FIELD EXPEDIENT ARM CARE SCREEN CAN IDENTIFY MUSCULOSKELETAL RISK FACTORS IN BASEBALL PLAYERS

5.1 Introduction

Musculoskeletal injury is commonly sustained by baseball players engaging in high level competitive sports. Alarmingly, the overall shoulder and elbow injury incidence for baseball players of all age levels has continued to rise over the last several decades.\textsuperscript{5,6,20,71,235} Despite development of pitch count and rest guidelines,\textsuperscript{219,236} non-traumatic MSK injuries due to overuse account for a large proportion of baseball related arm injuries.\textsuperscript{41} Consistently throwing with arm fatigue,\textsuperscript{4,17,18} or the presence of arm pain\textsuperscript{17} can increase injury risk and may be further compounded by deterioration of physical function. As a result, baseball coaches and sports medicine professionals cannot exclusively depend on managing throwing volume for injury prevention.\textsuperscript{31}

To attempt to mitigate overuse arm injuries, baseball coaches implement arm care programs to target MSK injury risk factors by improving strength, dynamic stability, and ROM of muscles and joints.\textsuperscript{42,237,238} Historically, arm care exercise programs consisted of generalized upper body strengthening or targeted stretching to a particular muscle group.\textsuperscript{161,163} Shitara et al\textsuperscript{88} reported a 36\% injury incidence reduction in high school (HS) baseball players who performed daily posterior rotator cuff stretching and strengthening exercises. Likewise, Bailey et al\textsuperscript{87} found that upper extremity instrumented manual therapy and self-stretching reduced shoulder ROM risk factors in active baseball players. However, these arm care programs tend to be more generalized as identification of specific injury risk factors in each player is difficult for coaches without an athletic trainer or physical therapist on staff.\textsuperscript{239}
Identification of key MSK risk factors is critical for proper arm care exercise programming and reduction of injury incidence rates. Current practice involves preseason screening to identify and manage players who possess injury risk factors.\textsuperscript{60,240,241} Researchers have identified several intrinsic risk factors which are inherent to the individual and can lead to development of injury. Although some intrinsic risk factors such as age\textsuperscript{7,48} and height\textsuperscript{48} are non-modifiable many intrinsic risk factors can be managed with intervention. Decreased ROM,\textsuperscript{82,83} strength imbalances,\textsuperscript{47} or asymmetries\textsuperscript{84,85} can manifest prior to the onset of symptoms or injury and typically can be modified with arm care exercise programs.\textsuperscript{40,86-88}

Physical limitations throughout the kinetic chain can contribute to upper extremity overuse injury in baseball players.\textsuperscript{34,242} The functional relationship between the upper extremities, spine, and hips required for kinetic linkage in rotational athletes warrants a more comprehensive screen of the entire body.\textsuperscript{171} Although the shoulder and elbow are common areas for symptom development, increased physiological stress on these joints can be produced by other remote regions in the body.\textsuperscript{135,243}

Most screening studies have captured risk factors through goniometric measurement involving a singular joint in isolation.\textsuperscript{177} MSK risk factors such as GIRD,\textsuperscript{46,68,82,100,112} limited hip IR ROM,\textsuperscript{40,138,142,144} limited hip ER ROM,\textsuperscript{141} thoracic spine mobility,\textsuperscript{49} GH TROM,\textsuperscript{54,82,99,100,102,112} and dynamic single leg balance\textsuperscript{50} have been identified during comprehensive pre-season examinations. However, pathological declines in MSK strength and ROM commonly occurs during the baseball season.\textsuperscript{32,93,244-247} Repetitive trauma due to overhead throwing and hitting can result in capsular thickening,\textsuperscript{248} muscle shortening,\textsuperscript{249} and altered neuromuscular control which can affect
the shoulders\textsuperscript{250} and hips.\textsuperscript{152} As a result, risk factors not present during preseason screening can develop as the season progresses.\textsuperscript{56,251} Furthermore, baseball coaches typically lack the training or time to remeasure the ROM of multiple joints throughout the season in an attempt to monitor for development of risk factors.\textsuperscript{252}

Injury risk factors could be better managed with more accurate and frequent MSK screening for early identification of risk factors,\textsuperscript{207} but to do so takes time and resources that may not be available to all competitive levels. The identification of players who possess specific risk factors or impairments is more challenging for youth, HS, or college level baseball coaches without essential sports medicine staff or resources.\textsuperscript{253} Many coaches fail to implement injury prevention programs because of a lack of perceived advantage over current practices,\textsuperscript{45} insufficient facilities or resources,\textsuperscript{252} or failure of the program to meet the team’s needs.\textsuperscript{252,254} Recently, a two-minute equipment free screening tool based on the principals of the Functional Movement Systems called the Arm Care Screen (ACS) has demonstrated excellent intra-rater ($k=0.76$; 95\% CI, 0.54-0.95) and inter-rater ($k=0.89$; 95\% CI, 0.77-0.99) reliability among HS baseball coaches. The simplicity of the ACS scoring criteria is convenient for coaches without readily available access to a rehabilitation professional, but the diagnostic value of the screening tool to identify potential risk factors is unknown.

To date there are no studies which have explored the discriminant validity of a field expedient screening tool that baseball coaches can use to accurately identify MSK mobility and balance risk factors. Additionally, the utility of the ACS to effectively screen for risk factors across different age levels is unknown. The primary purpose of this study was to investigate the accuracy of the ACS to detect common MSK risk factors in
baseball players. It was hypothesized that poor performance on the ACS subtests would be highly sensitive at detecting the presence of at least one associated MSK risk factor in youth, HS, and college baseball players. The secondary purpose of this study was to determine if the ACS can be utilized in youth, HS, and college level baseball players for identifying decreased ROM and balance limitations. It was hypothesized that youth, HS, and college level baseball players who failed the ACS subtests would have lower mean impairment measures compared to those who passed regardless of age level.

5.2 Materials and Methods

5.2.1 Study Design

A prospective cross-sectional design was used to establish the discriminability of the ACS to identify the presence of MSK risk factors among a cohort of baseball players. The Standards for Reporting Diagnostic Accuracy Studies (STARD) statement for a diagnostic accuracy study design was followed for standardized reporting. Approval was granted from the institutional review board at the University of Kentucky and informed consent and assent forms were obtained prior to data collection.

5.2.2 Participants

Based on an expected participant injury risk factor prevalence of 75%, a minimum sample size of 46 players was needed to detect a sensitivity of 0.90 on the ACS with a 0.10 confidence interval width. Anticipating a moderate effect size of 0.4 a sample of 49 participants in each group would have 80% power to detect an association between ACS failure and presence of MSK risk factors at an alpha of 0.05 for a two tailed test. Therefore, we planned an accrual target of 49 participants in each group for a final sample size of 147 baseball players.
A convenience sample of 110 male baseball players (youth \(n=30\), high school \(n=50\), college \(n=30\)) volunteered to participate in this study. The head coaches allowed the researchers to attend team workouts to recruit and test the players. The inclusion criteria required the participant to be a current and active member of a men’s youth, HS, or college baseball team. Exclusion criteria included the inability to participate in sport due to current injury, recent surgery (within three months), medical restriction from sports participation, recent concussion (within one month) or vestibular issue. Players under the age of 11 or older than 25 years were excluded.

5.2.3 Procedures

Data collection occurred over a six-month period during fall and winter offseason team workouts. Physical testing occurred during a single session prior to practice. Participants completed a demographic questionnaire which included information about their age, height, weight, playing position, baseball experience, and current injury status. All participants underwent ACS testing, ROM measurements of the shoulders, hips, thoracic spine, and dynamic balance testing.

5.2.4 The Arm Care Screen

The ACS is a modified movement-based screening tool which utilizes components of the FMS, SFMA, and YBT-LQ developed to improve field expediency and reduce scoring complexity. The ACS consists of three screens including, 1) reciprocal shoulder mobility, 2) 90/90 total body rotation, and 3) lower body (LB) diagonal reach. (Figure 4.2)
1. *Reciprocal Shoulder Mobility:* The participant began in standing with feet together and both hands open. The participant simultaneously reached one hand behind their head and other hand behind and up their back, similar to an Apley’s Scratch test position, assuming an extended and internally rotated position with one shoulder and a flexed and externally rotated position with the other. The arms should move in one smooth motion and tall posture should be maintained while the participant attempts to touch the fingertips of both hands together. Inability to touch right and left fingertips together in both reach directions was considered a failure on the test.

2. *90/90 Total Body Rotation:* The participant assumes a standing position with feet together, toes pointing forward and arms in the 90/90 position (90° shoulder abduction and 90° elbow flexion). The participant rotated their entire body including the hips, shoulders, and head as far as possible to the right while the foot position remained unchanged. Inability to see the back shoulder when viewed from behind on both sides was considered failure on the test.

3. *Lower Body Diagonal Reach:* The participant stood two shoe lengths away from a wall and while maintaining single leg balance on one foot the participant reaches with the opposite foot behind and across their body to touch the wall where it meets the ground five, then return to start position without touching the reach foot to the ground. To pass this test the athlete must repeat this maneuver five consecutive times without the foot touching down or losing balance. This has to be repeated with by reversing the leg position. Inability to touch the wall five consecutive times or loss of balance on either side was considered failure on the test.
Each component of the ACS was scored as pass or fail on both the right and left sides. Pain with testing was recorded but did not factor into the scoring criteria. For full description and illustrations on ACS testing procedures and scoring see Appendix 8 of this dissertation. All participants were video recorded performing the ACS testing procedures during the live testing. An iPhone 10X cell phone was placed approximately 15 feet directly posterior to the participant. A youth baseball coach with greater than five years of coaching experience electronically reviewed all video recordings and independently scored the ACS tests as pass or fail on each side. The results of the coaches’ ACS scoring results were used in the data analysis.

5.2.5 Musculoskeletal Impairment Measures

Following ACS testing, two pairs of physical therapists (JG/JK, AH/LB) with two-seven years of experience testing baseball players performed all ROM and balance impairment measures. The physical therapists (PT) were blinded to the results of the ACS testing. To improve reliability, the same PT from each pair always stabilized the joint and performed the passive movement while the other PT measured with the goniometer. Intra-rater and inter-rater reliability for all ROM and balance measures were established in 10 male individuals prior to beginning data collection. Intraclass correlation coefficients (ICC) for the PTs performing the testing was determined. Intra-rater (ICC \(3,k\) = 0.75-0.95) and inter-rater (ICC \(3,k\) = 0.79-0.97) reliability ranged from “good” to “excellent” for all measurements based on a mean-rating \((k=3)\), absolute agreement, and a two-way mixed effects model (Table 5.1).  

Glenohumeral Passive Range of Motion (PROM): Dominant and non-dominant GH IR, GH ER, and GH flexion PROM were measured on a portable treatment table with
a standard goniometer. Measurements for GH IR and ER PROM were performed with the participant in the supine position with the shoulder placed in 90° of abduction, elbow flexed to 90°, and neutral forearm rotation. A small towel was placed under the humerus to maintain the plane of the scapula. One examiner stabilized the scapula and passively internally or externally rotated the humerus until first resistance was achieved. A second examiner aligned a standard goniometer with the axis at the olecranon process, the stationary arm along the midline of the forearm.46 GH TROM was determined as the sum of ipsilateral GH ER and IR. GH flexion PROM was measured with the participant in supine with the knees bent. The arm was positioned in 0° shoulder abduction and elbow extension with the shoulder and forearm in neutral rotation. One examiner provided light stabilization to the lateral scapular border and passively elevated the shoulder in the sagittal plane until first resistance was achieved. The second examiner aligned the axis of the goniometer with the lateral aspect of the acromion process and the stationary arm along the midline of the humerus. The average of three trials for each measurement was used for analysis.115

*Thoracic Spine Rotation PROM:* The participant was placed in quadruped and instructed to sit with their hips back on their heels to maximally flex the hips. Upper extremities are positioned with elbows flexed and forearms together resting on a portable treatment table. The participant placed one upper extremity behind their back in the lower lumbar region. One examiner places a bubble inclinometer between the spinous processes of T1,2. While stabilizing the ipsilateral hips and torso, the second examiner grasps the contralateral anterior shoulder of the participant and passively rotates the thoracic spine
until first resistance is achieved. The examiner monitored for compensations such as excessive spinal sidebending, weight shifting, or inability of the hips to remain on the heels. The participant was encouraged to actively rotate their neck in sync with the thoracic rotation. Measurements were taken bilaterally and the average of three trials was used for analysis.130,132

*Hip Rotation PROM:* Hip internal and external rotation PROM was measured with the participant in prone on a portable treatment table with the hips adducted and the knees flexed to 90°. One examiner stabilized the pelvis and passively rotated the femur internally or externally until first resistance was achieved. The second examiner aligned a standard goniometer with the axis at the tibial tuberosity and the stationary arm along the midline of the tibia. Measurements were taken bilaterally and the average of three trials was used for analysis.57,257,258

*Y Balance Test - Posterolateral Reach (YBT-PL):* The YBT-PL was performed consistent with the protocol and testing kit developed by Plisky et al.259 The participant stood on the stance platform with shoes off and toes behind the red line. The participant was instructed to push the reach indicator in the posterolateral direction as far as possible with the free limb while maintaining balance on the stance limb. The trial was not counted if the participant lost their balance, touched the reaching foot to the ground, shoved the reach indicator, or rested on top of the reach indicator to gain support. To mitigate the learning effect, six practice trials were performed on the Y Balance Test kit followed by three trials which were scored and recorded. The average of the three scored trials was recorded and the same procedure was performed on the opposite leg.
5.2.6 Musculoskeletal Risk Factors

For the ACS to identify MSK risk factors, specific cutoff thresholds had to be established for each risk factor. Impairments below established physical impairment cutoff values were dichotomized as present or absent from previous literature when available. Nine MSK risk factors were measured by blinded PTs independent of the ACS scoring.

*Reciprocal Shoulder Mobility*

If any of the following shoulder or thoracic spine impairments were present during specific goniometric measures the athlete was dichotomized as possessing at least one MSK risk factor. These measures were compared to the reciprocal shoulder mobility screen outcome to determine test validity.

1. Limited GH IR PROM < 45°: If the dominant shoulder was measured to have less than 45° of internal rotation PROM at 90° abduction.\(^{100}\)

2. Glenohumeral internal rotation deficit > 20°: if the difference between nondominant GH IR and dominant GH IR was ≥ 20°.\(^{68,82}\)

3. GH TROM deficit (TROM-D) ≥ 10°: if the difference between dominant GH TROM and nondominant GH TROM was ≥ 10°.\(^{100-102}\)

4. GH flexion deficit ≥ 5°: if the difference between dominant GH flexion PROM and nondominant shoulder flexion PROM) ≥ 5°.\(^{99}\)

5. Thoracic spine rotation PROM < 50°: If the either dominant or nondominant thoracic rotation PROM was measured to have less than 50° in the quadruped position.\(^{260}\)
90/90 Total Body Rotation

If any of the following thoracic spine rotation described above (#5) or hip rotation PROM impairments were present during specific goniometric measures the athlete was dichotomized as having at least one MSK risk factor. These measures were compared to the 90/90 total body rotation screen outcome to determine test validity.

6. Hip IR PROM ≤ 36°: If either stance or stride hip was measured to have less than 36° of internal rotation PROM with the participant in prone.142,144

7. Hip ER PROM ≤ 40°: If either stance or stride hip was measured to have less than 40° of external rotation PROM with the participant in prone.141

Lower Body Diagonal Reach

If any of the following hip rotation PROM described above (#6 & #7) or dynamic single leg balance impairments were present during specific goniometric measures the athlete was dichotomized as possessing at least one MSK risk factors. These measures were compared to the LB diagonal reach screen to determine test validity.

8. Normalized YBT-PL reach distance: stance and stride leg YBT-PL reach were measured using the YBT test kit and protocol. To control for the effect of player height on absolute reach distance the YBT-PL reach was normalized by dividing the participant’s YBT-PL reach by their dominant LB limb length and multiplied by 100. The means of the normalized YBT-PL reach distances were calculated for each age level. YBT-PL reach distance performance below the lower third quartile for the youth (<92 cm), HS (<95 cm), and college (<98 cm) age levels were considered risk factors.261,262
9. YBT-PL reach asymmetry: If the absolute difference between stance and stride YBT-PL reach distance was $\geq 5.5$ cm.$^{263}$

5.2.7 Statistical Analysis

Descriptive statistics reported as average $\pm$ SD or frequency counts were calculated for all variables. The accuracy of the ACS to discriminate between players with at least one MSK injury risk factor was determined using cross tabulations. The presence of any corresponding MSK risk factor was dichotomized as described previously and entered into separate 2x2 tables for each component of the ACS. For the ACS reciprocal shoulder mobility screen, the reference standard was the goniometric measurement of MSK risk factors with the ACS as the clinical screen. A true positive (TP) was represented by the presence of at least one shoulder or thoracic mobility risk factor which was correctly identified by a positive ACS reciprocal shoulder mobility screen on either side. A true negative (TN) was indicated by the participant passing all the goniometric shoulder and thoracic ROM tests and testing negative on the reciprocal shoulder mobility screen bilaterally. A false positive (FP) was defined as the absence of any shoulder of thoracic risk factors but the participant tests positive on either side of the reciprocal shoulder mobility screen. A false negative (FN) occurred when a participant possesses at least one shoulder or thoracic risk factor but is negative on the reciprocal shoulder mobility screen bilaterally. The 2x2 tables for the 90/90 total body rotation and LB diagonal reach screens were constructed following a similar process. Univariate analyses were perform using the Chi-Square test for categorical variables to evaluate significant differences between ACS performance and those above or below the corresponding cutoff value. A
Fisher’s Exact test was used to measure the association if one or more cells had an expected count less than five. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratios (LR), and odds ratios (OR) were calculated with 95% confidence intervals to describe the accuracy of the ACS to detect MSK risk factors.

The discriminability of ACS performance on mean physical impairment measures was evaluated with a 3x2 analysis of variance (ANOVA) with three age levels (youth, HS, and college) and screen performance dichotomized as pass or fail. A Levene’s test was used to determine equal variances across all variables. A Level x Screen interaction was evaluated for significant interactions between all age levels and ACS screen performance. If no significant interaction was observed, main effects were examined to determine the magnitude of marginal mean differences between physical impairment measures and pass or fail performance on each ACS component. Mean differences for significant main or interaction effects were calculated from post hoc multiple comparisons with Tukey’s honest significant difference and Bonferroni adjustment were used to determine where the group differences existed. All data analyses were performed with SPSS statistical software (IBM SPSS Statistics for Mac, Version 27.0). An alpha level of $p < 0.05$ was considered statistically significant for all tests.

5.3 Results

A total of 110 male baseball players from six different teams met the inclusion and exclusion criteria and agreed to participate in the study. Demographic characteristics of all youth (n=30), HS (n=50), and college (n=30) level participants are provided in Table 5.2. The mean age ± SD of all participants in this sample was $16.6 \pm 3.1$, 29.1%
(n=32/110) were primarily pitchers, 65.5% (n=72/110) were infield or outfield position players, and 5.5% (n=6/110) were catchers.

Descriptive Analysis of ACS Performance and Measured MSK Risk Factors

The distribution of players with each risk factor among each age level based on ACS performance is reported in Table 5.3. Overall, players who failed the ACS components possessed a greater number of MSK risk factors compared to those who passed. High school and college level players demonstrated a greater frequency of shoulder, thoracic spine, and hip rotation ROM deficits compared to youth baseball players. High school players had the greatest number of dynamic balance risk factors followed by youth and college players.

Discriminant Validity of ACS by Level using Impairment Score Thresholds

Chi square tests showed significant associations for the 2x2 contingency tables created for each ACS component (p<0.001) across all age levels (Table 5.4). The prevalence of existing MSK risk factors among all three age groups ranged from 0.60-0.80 and the accuracy of each component of the ACS ranged from 0.60-0.80. Accuracy of the ACS to discriminate between those possessing MSK risk factors for each age level is reported in Table 5.5. Each ACS component demonstrated higher sensitivity ranging from 0.84-0.90 compared to specificity which ranged from 0.56-0.71. The sensitivity of the reciprocal shoulder mobility, 90/90 total body rotation, and LB diagonal reach screens were 0.90 (95% CI, 0.82-0.95), 0.85 (95% CI, 0.77-0.91), and 0.84 (95% CI, 0.76-0.90), respectively. Overall, baseball players with MSK risk factors were 10.8 (95% CI, 4.0-
29.1), 15.1 (95% CI, 5.5-42.8), and 13.4 (95% CI, 4.43-40.5) times greater odds for failing the reciprocal shoulder mobility screen, 90/90 total body rotation screen, or LB diagonal reach screen compared to player without MSK risk factors, respectively.

**Discriminant Validity of ACS by Level using Average Impairment Scores**

Interaction effects were evaluated to determine if differences existed between screen performance (pass or fail) and age level (youth, HS, college) for each screen separately. If a significant interaction was not present, then main effects and the mean differences ($\bar{x}_d$) were examined and compared to the minimal detectable change at the 95% level ($\text{MDC}_{95}$) for the measure (Tables 5.6-5.8).

**Shoulder Reciprocal Mobility**

No significant interactions effects were identified for the reciprocal shoulder mobility screen, but multiple main effects identified significantly reduced mobility in participants failing the shoulder mobility screen regardless of age groups. Significant main effects of reciprocal shoulder mobility screen included dominant and nondominant sides for GH IR PROM ($\bar{x}_d=7.2; 95\% \text{ CI}, 2.7-11.9, \text{MDC}_{95}=2.9^\circ$), GH TROM ($\bar{x}_d=8.5, 95\% \text{ CI}, 3.3-13.7, \text{MDC}_{95}=3.0^\circ$), GH flexion PROM ($\bar{x}_d=3.4, 95\% \text{ CI}, 0.003-5.8, \text{MDC}_{95}=3.0^\circ$), and thoracic rotation PROM ($\bar{x}_d=7.1, 95\% \text{ CI}, 3.3-11.1, \text{MDC}_{95}=2.8^\circ$) (Table 5.6). All significant $\bar{x}_d$ exceeded the MDC$_{95}$ for the measures (Table 5.1). There were no significant main effect differences for nondominant GH ER PROM ($p=0.067$) and dominant ($p=0.864$) GH ER PROM (Table 5.6).

**90/90 Total Body Rotation**

There was a significant interaction between age level and the 90/90 total body rotation test screen outcome observed for dominant ($p=0.036$) and nondominant thoracic...
rotation ($p=0.043$). Multiple comparisons post hoc testing showed thoracic rotation
PROM significantly differed in HS and college players based on screen performance but
not among in youths. (Table 5.7). Main effect differences were observed with lower mo-
bility values for stance hip IR PROM ($\bar{x}_d=5.2$, 95% CI, 1.7-8.5, MDC$_{95}$=3.0°) and stride
hip IR PROM ($\bar{x}_d=4.7$, 95% CI, 0.61-8.6, MDC$_{95}$=2.8°). All significant mean differ-
ences exceeded the (MDC$_{95}$) for the measure. There was no significant main effect for
stride ($p=0.067$) and stance hip ER PROM ($p=0.196$) (Table 5.7).

**Lower Body Diagonal Reach**

No significant interactions effects were identified for the LB diagonal reach
screen, but multiple main effects identified significant reduced mobility or balance in par-
ticipants failing the screen regardless of age groups. Participants who failed the LB diag-
ogonal reach screen had lower dynamic balance values in both the stance ($\bar{x}_d=7.4$; 95% CI,
3.6-11.2, MDC$_{95}$=3.7°) and stride ($\bar{x}_d=6.3$; 95% CI, 2.8-9.5, MDC$_{95}$=3.7°) sides for the
YBT-PL reach. Lower ROM values were observed for stride hip IR PROM ($\bar{x}_d=4.7$, 95% CI,
0.92-8.4, MDC$_{95}$=3.2°), and stance hip IR PROM ($\bar{x}_d=3.7$, 95% CI, 0.51-6.8, MDC$_{95}$
=3.2°) in those who failed the LB diagonal reach screen. All significant mean differences
exceeded the MDC$_{95}$ for the measure. There was no significant main effect for stride
($p=0.230$) and stance ($p=0.267$) hip ER PROM (Table 5.8).

**5.4 Discussion**

The goal of the ACS was to evaluate global movement patterns with the assump-
tion that inability to meet the passing criteria would be associated with a corresponding
local impairment. Since the reason for movement pattern limitations could vary among
individuals and change over the course of a season, we expected the ACS to capture at
least one MSK risk factor which could be affecting the global movement pattern. The 
findings from this study support the primary hypothesis that the ACS components can ac-
curately discriminate between baseball players with or without MSK risk factors. All 
three components of the ACS exhibited high sensitivity for detecting at least one corre-
responding MSK risk factors. Furthermore, players with MSK risk factors had a signifi-
cantly greater probability and odds of failing the ACS components regardless of age 
level. Therefore, baseball coaches working with youth, HS, or college level players can 
confidently use the ACS to screen their players for MSK risk factors.

Baseball players commonly present with normal asymmetries in shoulder rotation 
ROM because of a humeral retrotorsion adaptation. Shoulder asymmetries can be iden-
tified by taking precise measurements of the shoulder and comparing differences in domi-
nant and nondominant GH TROM. However, movement screening procedures have 
been less helpful at recognizing TROM differences. Sprague et al found no relation-
ship between FMS shoulder mobility asymmetry and GH TROM differences >10°. Con-
versely, the current study found a significant relationship between participants who failed 
the reciprocal shoulder mobility screen and those who had reduced mean GH TROM ≥ 
10 degrees. The ACS reciprocal shoulder mobility passing criteria requires more ROM to 
pass compared to the FMS fist to fist shoulder mobility test which may have magnified 
the GH TROM limitation.

Deficits in dominant GH internal rotation ROM are normal adaptations for over-
head throwing athletes. However, dominant GH IR ROM limitations that become too 
great are commonly associated with increased injury risk. Shanley et al found that HS 
baseball players with a ≥ 25° GIRD were 3.7 (RR=3.7; 95% CI, 1.6-8.9) times greater
risk for injury. Ostrander et al\textsuperscript{105} reported that GH IR ROM loss did not differ between HS, college, or professional level pitchers. However, pitchers with a UCL tear had on average 21° of GH IR ROM loss compared to 13° of average GH IR loss in those without a UCL tear. In the current study, extreme limitations in GH IR ROM and GIRD were detected by the reciprocal shoulder mobility screen. There were no HS or college level players who passed the reciprocal shoulder mobility screen and had less than 45° of GH IR PROM or GIRD greater than 20 degrees. This suggests that the ACS reciprocal shoulder mobility screen can serve as quick and accurate tool for ruling out GH IR and GIRD limitations.

Interestingly, ACS performance was consistently unable to detect limitations associated with GH ER ROM. This is concerning as GH ER ROM limitations are associated with injury in baseball players. Camp et al\textsuperscript{116} reported that the odds of an elbow injury increased 7\% for every 1° loss in GH ER ROM. Likewise, Wilk et al\textsuperscript{115} found that professional baseball players were more than two times increased risk for injury and four-fold increased risk for surgery if their dominant shoulder had less ER ROM compared to the nondominant side. It is possible that the reciprocal shoulder mobility screen does not sufficiently challenge GH ER ROM beyond 90 degrees. Therefore, this test may need to the modified or a different test included in the ACS protocol to better capture ER ROM.

Poor movement at the thoracic spine can disrupt the kinetic chain sequence, lead to undesired compensation of the low back and shoulder girdle, and lead to MSK injury.\textsuperscript{135,136} Decreased thoracic spine ROM is associated with increased kyphosis and scapular protraction which could limit shoulder mobility\textsuperscript{267} and contribute to the development of pain.\textsuperscript{268} Sakata et al\textsuperscript{49} reported that reduced thoracic spine mobility increased risk for
injury in baseball players 2.5-fold. Interestingly, 42% (n=31/73) of participants who failed the reciprocal shoulder mobility screen had limited thoracic spine mobility. The “lumbar locked” thoracic rotation test was used in this study to establish thoracic spine mobility deficits. Although thoracic spine extension is the primary component occurring during the reciprocal shoulder mobility screen, biomechanically spinal rotation is created by contralateral flexion and ipsilateral extension coupling.\textsuperscript{269} Therefore, bilateral measurement of thoracic rotation would provide a reasonable assessment of thoracic extension mobility. The results of the present study suggest that thoracic spine mobility deficits are prevalent especially among HS and college level players.

An appropriate connection between the upper extremity, spine, and lower extremities must be established for optimal energy generation and transfer to occur during overhead throwing.\textsuperscript{121,122} The goal of the 90/90 total body rotation screen was to evaluate the interaction of thoracic spine rotation and hip rotation collectively. Screening the thoracic spine and hips independently is less desirable since the upper and lower body must function simultaneously during rotational sports. Risk factors throughout the entire kinetic chain have been identified in baseball players as potentially contributing to injury. The lower quarter has been implicated for contributing to injury risk when not functioning ideally. Sekiguchi et al\textsuperscript{144} reported that stride hip IR ROM $< 36^\circ$ was associated with elbow or shoulder pain (OR$=1.08$; 95% CI, 1.01-1.15) in youth baseball players. In the current study, there was an equal distribution of thoracic spine and hip rotation limitations in players who failed the 90/90 total body rotation.
Deficits in single leg balance leads to poor lumbopelvic control and can disrupt the kinetic sequencing of throwing motion and require a greater contribution from the upper extremity to develop the force needed for pitching performance. The goal of the LB diagonal reach screen was to evaluate dynamic single leg balance near the limits of the player’s hip rotational ability. Stride hip IR mobility deficits < 36° were found in 41% (n=31/75) participants who failed the LB diagonal reach screen. Previous research has reported that normal hip IR and ER ROM is associated with better dynamic balance performance. Interestingly, the current study showed that stance hip ER was not associated with failure on the LB diagonal reach test. Closed kinetic chain hip ER is the primary component occurring on the stance limb of the diagonal reach. However, it appears that limited hip IR mobility of the stance and stride limb may have contributed most to the outcome of the screen. These findings differ from a study conducted by Nakagawa et al who reported the hip IR ROM was not significantly correlated to YBT-PL performance. However, in the same study the authors reported that trunk extensor endurance was strongly correlated (r=0.522, p=0.001) and explained 27% of YBT-PL performance. Poor performance on the LB diagonal reach test in the present study may have been capturing both hip mobility limitations and poor core stability or endurance in the baseball players sampled.

The secondary purpose of this study was to determine if the ACS can identify baseball players with decreased ROM and balance. This hypothesis was supported by the current study as youth, HS, and college level players who failed the ACS demonstrated lower ROM and balance scores in all corresponding impairment measures except for shoulder and hip ER PROM. This study included baseball players of various age levels.
ranging from youth players as young as 11 to college level players as old as 23 years. Considering that these athletes likely demonstrated different phenotypes we selected to compared youth, HS, and college level players. College and HS level players tended to have more mobility related risk factors such as shoulder TROM-D, reduced shoulder IR PROM, and thoracic spine rotation limitations compared to youth level players. However, youth and HS players displayed more asymmetries and dysfunction in dynamic single leg balance. One could theorize that younger players tended to have more overall upper body mobility, but poorer neuromuscular control and strength compared to older players. Conversely, college level players tend to have more hip rotation ROM limitations but better neuromuscular control. Interestingly, hip IR ROM limitations were consistently detected throughout this sample regardless of age level. This is consistent with previous literature which has identified decreased hip IR ROM as a risk factor for injury in youth,\textsuperscript{40,142} HS,\textsuperscript{144} and college\textsuperscript{140} baseball players.

Multimodal arm care exercise programs have targeted several different MSK risk factors to mitigate injury incidence. In a prospective cohort, Sakata et al\textsuperscript{40} reported that improvements in GH TROM, stride hip IR PROM, and thoracic spine mobility were the most predictive variables associated with reduced odds of medial elbow injury in 305 youth baseball players. In the current study, numerous MSK risk factors throughout the kinetic chain were plausible impairments that the ACS could identify. The most prevalent risk factors detected by a failed reciprocal shoulder mobility screen included limited GH IR PROM, GH TROM-D, and decreased thoracic spine rotation PROM. Likewise, the LB diagonal reach detected a disproportionate number of dynamic balance limitations
and asymmetries, especially in youth and HS players. However, hip ER, hip IR, and tho-
racic rotation risk factors were more evenly distributed relative to poor performance on
the 90/90 total body rotation screen. This could provide baseball coaches and healthcare
providers with more guidance as to which risk factors are being identified during the
screening process. As a result, the ACS may serve as a useful tool for detecting declining
mobility and is a valid measure for distinguishing between unique limitations in mobility
and balance in youth, HS, and college level baseball players.

Identifying the presence of these risk factors in baseball players is difficult for
coaches who have limited time to measure each joint or impairment involved in throwing.
The ACS is a simple screen which can aid the medical staff or coaches in identifying po-
tential impairments that need to be addressed to minimize injury risk factors. In the cur-
rent study, MSK risk factors are two-three times more likely to be present in those who
tested positive on the ACS. When examining -LR, baseball players who do not have
MSK risk factors were approximately five times more likely to pass compared to those
who failed. The prevalence of MSK risk factors was high in this sample limiting confi-
dence in interpretation of PPV due to oversaturation of risk factors. Due to its high sensi-
tivity and NPV and low -LR, the ACS can serve as a true screening tool effectively ruling
out the presence of risk factors given a negative test. Implementation of the ACS would
allow coaches to capture players with MSK risk factors, as well as some players who
were falsely positive without risk factors. Inclusion of baseball players without MSK risk
factors is less problematic in this case because additional arm care exercises will likely
not create harm.
In the current study, it was determined that poor performance on the individual components of the ACS was associated with the presence of corresponding injury risk factors, thus requiring targeted exercise intervention. Baseball coaches routinely implement group-based arm care programs to maintain strength, flexibility, and prevent injuries. However, modification of arm care exercises may be required to adjust for the development of new impairments or risk factors as the season progresses. Resources and staffing limitations prevent many teams at various levels from performing comprehensive MSK assessments and testing on their players multiple times during the season. The ACS provides health care professionals and coaches with a tool to track changes in movement quality and decreased physical function so that exercise intervention can be recommended prior to the onset of injury. Future research should investigate the inability of the ACS to detect changes in MSK function throughout the season. Furthermore, investigation relative to the predictive validity of the ACS to identify baseball players who are at risk for injury is warranted.

5.5 Limitations

The results of this study should be interpreted conservatively as it is not without limitations. First, if a population specific injury risk factor had not been established then meaningful impairments were determined from the normative values in the literature. Although not a known risk factor, this degree of dysfunction likely has negative effects on performance and could lead to overuse injury. Second, the sample size is underpowered particularly in the youth in the college level players. A larger sample size may have resulted in a higher SN and narrower confidence intervals consistent with the HS subgroup. Finally, the current study focused on youth, HS, and college baseball players who played
a variety of positions. The results of this study may not be generalizable to baseball players at the professional level or female softball players. We included only male baseball players to maximize homogeneity of our sample since the pitching mechanism and injury risk factors vary in softball players, however, we also included both position players and pitchers. Musculoskeletal function differs between pitchers and position players and likely resulted in increased heterogeneity among our participants.

5.6 Conclusions

The ACS is a feasible screening tool which can be administered in less than three minutes to discriminate between common MSK risk factors associated with injuries in youth, high school, and college level baseball players. The ACS components demonstrate high sensitivity for correctly identifying MSK risk factors common in baseball players and can be useful as screening tools for baseball coaches and health care professional in developing and potentially monitoring arm care exercise programs.
Table 5.1  Pretesting Intra-rater and Inter-rater Reliability

<table>
<thead>
<tr>
<th></th>
<th>Inter-rater Reliability</th>
<th>Inter-rater Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>ICC (95% CI)</td>
</tr>
<tr>
<td>GH IR PROM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team A</td>
<td>63.8 (9.3)</td>
<td>0.83 (0.56-0.93)</td>
</tr>
<tr>
<td>Team B</td>
<td>60.7 (9.2)</td>
<td>0.93 (0.82-0.97)</td>
</tr>
<tr>
<td>GH ER PROM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team A</td>
<td>82.5 (8.9)</td>
<td>0.85 (0.62-0.94)</td>
</tr>
<tr>
<td>Team B</td>
<td>81.2 (9.6)</td>
<td>0.92 (0.73-0.97)</td>
</tr>
<tr>
<td>GH Flexion PROM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team A</td>
<td>167.1 (9.2)</td>
<td>0.78 (0.44-0.91)</td>
</tr>
<tr>
<td>Team B</td>
<td>159.1 (8.5)</td>
<td>0.89 (0.73-0.96)</td>
</tr>
<tr>
<td>Thoracic Rotation PROM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team A</td>
<td>50.8 (8.7)</td>
<td>0.90 (0.75-0.96)</td>
</tr>
<tr>
<td>Team B</td>
<td>52.7 (9.1)</td>
<td>0.73 (0.31-0.89)</td>
</tr>
<tr>
<td>Hip IR PROM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team A</td>
<td>34 (9.9)</td>
<td>0.75 (0.40-0.90)</td>
</tr>
<tr>
<td>Team B</td>
<td>40 (9.8)</td>
<td>0.94 (0.78-0.98)</td>
</tr>
<tr>
<td>Hip ER PROM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team A</td>
<td>39.7 (8.9)</td>
<td>0.88 (0.69-0.95)</td>
</tr>
<tr>
<td>Team B</td>
<td>40.1 (7.7)</td>
<td>0.92 (0.79-0.97)</td>
</tr>
<tr>
<td>Posterolateral reach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team A</td>
<td>102 (11.8)</td>
<td>0.95 (0.65-0.99)</td>
</tr>
<tr>
<td>Team B</td>
<td>101.3 (12.3)</td>
<td>0.95 (0.86-0.98)</td>
</tr>
</tbody>
</table>

*SD = Standard Deviation, SEM = Standard Error of the Mean, CI = Confidence Interval, ICC = Intraclass Correlation Coefficient, MDC = minimal detectable change
Table 5.2 Descriptive Characteristics of Baseball Players

<table>
<thead>
<tr>
<th>Variables</th>
<th>Youth (n=30)</th>
<th>HS (n=50)</th>
<th>College (n=30)</th>
<th>ALL (n=110)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>13.1 ± 0.82</td>
<td>16.3 ± 1.13</td>
<td>20.6 ± 1.8</td>
<td>16.6 ± 3.1</td>
</tr>
<tr>
<td>Height, cm</td>
<td>164.6 ± 9.5</td>
<td>177.7 ± 7.4</td>
<td>185.0 ± 5.5</td>
<td>176.1 ± 10.8</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>55.3 ± 11.3</td>
<td>74.7 ± 10.6</td>
<td>91.4 ± 9.2</td>
<td>74.0 ± 16.9</td>
</tr>
<tr>
<td>Dominant limb, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>28 (93.3)</td>
<td>45 (90.0)</td>
<td>24 (80.0)</td>
<td>97 (88.2)</td>
</tr>
<tr>
<td>Left</td>
<td>2 (6.7)</td>
<td>5 (10.0)</td>
<td>6 (20.0)</td>
<td>13 (11.8)</td>
</tr>
<tr>
<td>Years of Baseball Experience</td>
<td>8.4 ± 1.8</td>
<td>10.7 ± 2.6</td>
<td>15.9 ± 2.3</td>
<td>11.6 ± 3.7</td>
</tr>
<tr>
<td>Primary Position, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pitcher</td>
<td>6 (20.0)</td>
<td>10 (20.0)</td>
<td>16 (53.3)</td>
<td>32 (29.1)</td>
</tr>
<tr>
<td>Catcher</td>
<td>2 (6.7)</td>
<td>2 (4.0)</td>
<td>2 (6.7)</td>
<td>6 (5.5)</td>
</tr>
<tr>
<td>Infield Player</td>
<td>17 (56.7)</td>
<td>21 (42.0)</td>
<td>10 (33.3)</td>
<td>48 (43.6)</td>
</tr>
<tr>
<td>Outfield Player</td>
<td>5 (16.7)</td>
<td>17 (34.0)</td>
<td>2 (6.7)</td>
<td>24 (21.8)</td>
</tr>
</tbody>
</table>

*HS=high school, SD=standard deviation, y=year
Table 5.3  Distribution of Players by Age Level with MSK Risk Factors

<table>
<thead>
<tr>
<th></th>
<th>Failed</th>
<th>Passed</th>
<th>No Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Youth (n=30)</td>
<td>HS (n=50)</td>
<td>College (n=30)</td>
</tr>
<tr>
<td>Dom Shoulder IR PROM &lt;45°</td>
<td>1</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>GIRD ≥20°</td>
<td>0</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>TROM deficit ≥10°</td>
<td>2</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Shoulder flexion deficit ≥5°</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Dom Thoracic PROM &lt;50°</td>
<td>3</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Nondom Thoracic PROM &lt;50°</td>
<td>3</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Failed</td>
<td>Passed</td>
<td>No Risk Factor</td>
</tr>
<tr>
<td></td>
<td>Youth (n=30)</td>
<td>HS (n=50)</td>
<td>College (n=30)</td>
</tr>
<tr>
<td>Dom Thoracic PROM &lt;50°</td>
<td>3</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Nondom Thoracic PROM &lt;50°</td>
<td>3</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Stance Hip IR PROM ≤36°</td>
<td>5</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Stride Hip IR PROM ≤36°</td>
<td>8</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Stance Hip ER PROM ≤40°</td>
<td>6</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Stride Hip ER PROM ≤40°</td>
<td>9</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Failed</td>
<td>Passed</td>
<td>No Risk Factor</td>
</tr>
<tr>
<td></td>
<td>Youth (n=30)</td>
<td>HS (n=50)</td>
<td>College (n=30)</td>
</tr>
<tr>
<td>Stance YBT-PL ≤92, 95, 98 cm</td>
<td>8</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Stride YBT-PL ≤92, 95, 98 cm</td>
<td>6</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>YBT-PL asymmetry &gt;5.5 cm</td>
<td>7</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Stance Hip IR PROM ≤36°</td>
<td>6</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>Stride Hip IR PROM ≤36°</td>
<td>7</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>Stance Hip ER PROM ≤40°</td>
<td>4</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Stride Hip ER PROM ≤40°</td>
<td>7</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>

* Dom = dominant, Nondom = nondominant, IR = internal rotation, ER = external rotation, GIRD = glenohumeral internal rotation deficit, TROM = total range of motion, PROM = passive range of motion, YBT-PL = Y Balance Test-Posterolateral Reach
Table 5.4  2x2 Contingency Tables of ACS Components  
(n=110)

<table>
<thead>
<tr>
<th>Reciprocal Shoulder Mobility Screen</th>
<th>90/90 Total Body Rotation Screen</th>
<th>Lower Body Diagonal Reach Screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥1 Risk Factor</td>
<td>≥1 Risk Factor</td>
<td>≥ 1 Risk Factor</td>
</tr>
<tr>
<td>Reciprocal Shoulder Mobility</td>
<td>90/90 Total Body Rotation</td>
<td>LB Diagonal Reach</td>
</tr>
<tr>
<td>Fail</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>60</td>
<td>69</td>
<td>75</td>
</tr>
<tr>
<td>19</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>24</td>
<td>21</td>
<td>15</td>
</tr>
</tbody>
</table>

$p$ value = 0.001

<table>
<thead>
<tr>
<th>Estimate</th>
<th>95% CI</th>
<th>Estimate</th>
<th>95% CI</th>
<th>Estimate</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy:</td>
<td>0.76</td>
<td>0.67 to 0.83</td>
<td>Accuracy:</td>
<td>0.82</td>
<td>0.73 to 0.88</td>
</tr>
<tr>
<td>Prevalence:</td>
<td>0.60</td>
<td>0.5 to 0.70</td>
<td>Prevalence:</td>
<td>0.74</td>
<td>0.65 to 0.82</td>
</tr>
</tbody>
</table>

\(\text{ACS}=\text{Arm Care Screen}, \text{PPV}=\text{positive predictive value}, \text{NPV}=\text{negative predictive value}, +\text{LR}=\text{positive likelihood ratio}, -\text{LR}=\text{negative likelihood ratio}, \text{OR}=\text{odds ratio}, \text{CI}=\text{confidence interval}\)
Table 5.5  Accuracy of ACS Components at Identifying Injury Risk Factors

<table>
<thead>
<tr>
<th></th>
<th>SN, (95% CI)</th>
<th>SP, (95% CI)</th>
<th>PPV, (95% CI)</th>
<th>NPV, (95% CI)</th>
<th>+LR, (95% CI)</th>
<th>-LR, (95% CI)</th>
<th>OR, (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shoulder Mobility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youth (n=30)</td>
<td>0.75 (0.56, 0.88)</td>
<td>0.72 (0.52, 0.86)</td>
<td>0.64 (0.45, 0.80)</td>
<td>0.81 (0.62, 0.92)</td>
<td>2.70 (1.20, 6.09)</td>
<td>0.35 (0.13, 0.97)</td>
<td>7.8 (1.48, 41.2)</td>
</tr>
<tr>
<td>HS (n=50)</td>
<td>0.93 (0.81, 0.98)</td>
<td>0.40 (0.27, 0.55)</td>
<td>0.70 (0.55, 0.82)</td>
<td>0.80 (0.66, 0.89)</td>
<td>1.56 (1.08, 2.26)</td>
<td>0.17 (0.04, 0.72)</td>
<td>9.3 (1.72, 50.6)</td>
</tr>
<tr>
<td>College (n=30)</td>
<td>0.92 (0.75, 0.98)</td>
<td>0.60 (0.41, 0.77)</td>
<td>0.92 (0.75, 0.98)</td>
<td>0.60 (0.41, 0.77)</td>
<td>2.3 (0.78, 6.77)</td>
<td>0.13 (0.03, 0.59)</td>
<td>17.3 (1.7, 172)</td>
</tr>
<tr>
<td>ALL (n=110)</td>
<td>0.90 (0.82, 0.95)</td>
<td>0.56 (0.46, 0.65)</td>
<td>0.76 (0.67, 0.83)</td>
<td>0.77 (0.68, 0.84)</td>
<td>2.03 (1.44, 2.87)</td>
<td>0.19 (0.09, 0.40)</td>
<td>10.8 (4.0, 29.1)</td>
</tr>
<tr>
<td><strong>Total Body Rotation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youth (n=30)</td>
<td>0.82 (0.63, 0.93)</td>
<td>0.75 (0.56, 0.88)</td>
<td>0.90 (0.72, 0.97)</td>
<td>0.60 (0.41, 0.77)</td>
<td>3.27 (0.97, 11.0)</td>
<td>0.24 (0.09, 0.63)</td>
<td>13.5 (1.95, 93.3)</td>
</tr>
<tr>
<td>HS (n=50)</td>
<td>0.86 (0.73, 0.94)</td>
<td>0.79 (0.65, 0.89)</td>
<td>0.91 (0.79, 0.97)</td>
<td>0.69 (0.54, 0.81)</td>
<td>4.02 (1.46, 11.1)</td>
<td>0.18 (0.08, 0.42)</td>
<td>22.7 (4.64, 111)</td>
</tr>
<tr>
<td>College (n=30)</td>
<td>0.87 (0.69, 0.96)</td>
<td>0.57 (0.38, 0.74)</td>
<td>0.87 (0.69, 0.96)</td>
<td>0.57 (0.38, 0.74)</td>
<td>2.03 (0.85, 4.85)</td>
<td>0.23 (0.07, 0.79)</td>
<td>8.9 (1.29, 61.1)</td>
</tr>
<tr>
<td>ALL (n=110)</td>
<td>0.85 (0.77, 0.91)</td>
<td>0.72 (0.62, 0.80)</td>
<td>0.90 (0.82, 0.95)</td>
<td>0.64 (0.54, 0.73)</td>
<td>3.09 (1.70, 5.61)</td>
<td>0.20 (0.11, 0.35)</td>
<td>15.1 (5.5, 42.8)</td>
</tr>
<tr>
<td><strong>LB Diagonal Reach</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youth (n=30)</td>
<td>0.88 (0.70, 0.96)</td>
<td>0.67 (0.47, 0.82)</td>
<td>0.91 (0.74, 0.98)</td>
<td>0.57 (0.38, 0.74)</td>
<td>2.63 (0.84, 8.24)</td>
<td>0.19 (0.06, 0.63)</td>
<td>14.0 (1.74, 113)</td>
</tr>
<tr>
<td>HS (n=50)</td>
<td>0.88 (0.75, 0.95)</td>
<td>0.78 (0.64, 0.88)</td>
<td>0.95 (0.84, 0.99)</td>
<td>0.58 (0.43, 0.72)</td>
<td>3.95 (1.16, 13.5)</td>
<td>0.16 (0.07, 0.39)</td>
<td>25.2 (4.05, 157)</td>
</tr>
<tr>
<td>College (n=30)</td>
<td>0.78 (0.59, 0.90)</td>
<td>0.71 (0.51, 0.85)</td>
<td>0.90 (0.72, 0.97)</td>
<td>0.50 (0.32, 0.68)</td>
<td>2.74 (0.83, 9.02)</td>
<td>0.30 (0.12, 0.74)</td>
<td>9.0 (1.32, 61.1)</td>
</tr>
<tr>
<td>ALL (n=110)</td>
<td>0.84 (0.76, 0.90)</td>
<td>0.71 (0.61, 0.79)</td>
<td>0.93 (0.86, 0.97)</td>
<td>0.52 (0.42, 0.62)</td>
<td>2.95 (1.49, 5.84)</td>
<td>0.22 (0.13, 0.38)</td>
<td>13.4 (4.43, 40.5)</td>
</tr>
</tbody>
</table>

\(^a\) ACS=Arm Care Screen, SN=sensitivity, SP=specificity, PPV=positive predictive value, NPV=negative predictive value, +LR=positive likelihood ratio, -LR=negative likelihood ratio, OR=odds ratio, CI=confidence interval.
<table>
<thead>
<tr>
<th>Impairment Measure</th>
<th>Reciprocal Shoulder Screen</th>
<th>Main Effect</th>
<th>Main Effect</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pass</td>
<td>Fail</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Dom GH IR,°</td>
<td>Youth (n=30)</td>
<td>68.8 ± 6.6</td>
<td>58.5 ± 13.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HS (n=50)</td>
<td>58.4 ± 12.0</td>
<td>55.8 ± 12.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>College (n=30)</td>
<td>61.0 ± 12.5</td>
<td>54.4 ± 8.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total (n=110)</td>
<td>63.5 ± 10.5</td>
<td>56.3 ± 11.0</td>
<td>7.2 (2.7, 11.9)</td>
</tr>
<tr>
<td>Nondom GH IR,°</td>
<td>Youth (n=30)</td>
<td>72.6 ± 8.1</td>
<td>59.9 ± 9.3</td>
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</tr>
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<td>HS (n=50)</td>
<td>68.5 ± 9.5</td>
<td>61.2 ± 12.4</td>
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</tr>
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<td></td>
<td>College (n=30)</td>
<td>64.7 ± 7.5</td>
<td>59.9 ± 9.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total (n=110)</td>
<td>68.7 ± 9.0</td>
<td>60.5 ± 10.3</td>
<td>8.2 (4.3, 12.1)</td>
</tr>
<tr>
<td>Dom GH ER,°</td>
<td>Youth (n=30)</td>
<td>94.8 ± 6.2</td>
<td>95.0 ± 8.0</td>
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<td>HS (n=50)</td>
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<td>91.0 ± 10.1</td>
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<td>College (n=30)</td>
<td>100.4 ± 7.6</td>
<td>96.0 ± 10.4</td>
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<td>Total (n=110)</td>
<td>94.8 ± 9.5</td>
<td>94.6 ± 9.7</td>
<td>0.29 (-3.5, 4.2)</td>
</tr>
<tr>
<td>Nondom GH ER,°</td>
<td>Youth (n=30)</td>
<td>91.0 ± 6.5</td>
<td>90.9 ± 7.6</td>
<td></td>
</tr>
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<td>HS (n=50)</td>
<td>90.0 ± 9.4</td>
<td>85.3 ± 8.6</td>
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<td>College (n=30)</td>
<td>94.6 ± 6.8</td>
<td>89.9 ± 6.1</td>
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<td>Total (n=110)</td>
<td>91.0 ± 8.1</td>
<td>88.1 ± 7.9</td>
<td>2.9 (-0.23, 6.5)</td>
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<tr>
<td>Dom GH TROM,°</td>
<td>Youth (n=30)</td>
<td>162.9 ± 12.7</td>
<td>148.4 ± 7.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HS (n=50)</td>
<td>157.9 ± 13.9</td>
<td>151.4 ± 14.8</td>
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<tr>
<td></td>
<td>College (n=30)</td>
<td>154.2 ± 11.0</td>
<td>152.9 ± 6.9</td>
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<tr>
<td></td>
<td>Total (n=110)</td>
<td>158.4 ± 13.1</td>
<td>151.1 ± 11.2</td>
<td>8.5 (3.3, 13.7)</td>
</tr>
<tr>
<td>Nondom GH TROM,°</td>
<td>Youth (n=30)</td>
<td>163.1 ± 10.8</td>
<td>155.7 ± 12.4</td>
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<td></td>
<td>HS (n=50)</td>
<td>156.1 ± 12.2</td>
<td>153.1 ± 13.6</td>
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<tr>
<td></td>
<td>College (n=30)</td>
<td>163.4 ± 4.3</td>
<td>151.4 ± 9.7</td>
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<tr>
<td></td>
<td>Total (n=110)</td>
<td>159.7 ± 11.2</td>
<td>153.1 ± 12.1</td>
<td>6.6 (2.4, 12.5)</td>
</tr>
<tr>
<td>Dom GH Flex,°</td>
<td>Youth (n=30)</td>
<td>171.6 ± 6.6</td>
<td>166.6 ± 8.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HS (n=50)</td>
<td>171.7 ± 6.9</td>
<td>165.5 ± 9.7</td>
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</tr>
<tr>
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<td>College (n=30)</td>
<td>168.2 ± 7.8</td>
<td>168.4 ± 5.3</td>
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<tr>
<td></td>
<td>Total (n=110)</td>
<td>171.1 ± 7.0</td>
<td>167.7 ± 7.2</td>
<td>3.4 (0.003, 5.8)</td>
</tr>
<tr>
<td>Nondom GH Flex,°</td>
<td>Youth (n=30)</td>
<td>177.1 ± 4.2</td>
<td>171.4 ± 7.0</td>
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</tr>
<tr>
<td></td>
<td>HS (n=50)</td>
<td>174.7 ± 4.3</td>
<td>170.8 ± 7.2</td>
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</tr>
<tr>
<td></td>
<td>College (n=30)</td>
<td>173.4 ± 4.4</td>
<td>170.3 ± 7.1</td>
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</tr>
<tr>
<td></td>
<td>Total (n=110)</td>
<td>175.4 ± 4.4</td>
<td>171.1 ± 7.0</td>
<td>4.3 (1.2, 6.6)</td>
</tr>
<tr>
<td>Dom Thoracic Rot,°</td>
<td>Youth (n=30)</td>
<td>57.9 ± 8.0</td>
<td>54.4 ± 5.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HS (n=50)</td>
<td>62.8 ± 9.7</td>
<td>55.0 ± 8.7</td>
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<tr>
<td></td>
<td>College (n=30)</td>
<td>57.2 ± 9.5</td>
<td>48.1 ± 8.6</td>
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<tr>
<td></td>
<td>Total (n=110)</td>
<td>60.0 ± 9.1</td>
<td>52.9 ± 8.5</td>
<td>7.1 (3.3, 11.1)</td>
</tr>
<tr>
<td>Nondom Thoracic Rot,°</td>
<td>Youth (n=30)</td>
<td>64.0 ± 8.3</td>
<td>57.4 ± 7.5</td>
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<tr>
<td></td>
<td>HS (n=50)</td>
<td>66.5 ± 8.4</td>
<td>56.3 ± 8.3</td>
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</tr>
<tr>
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<td>College (n=30)</td>
<td>61.3 ± 9.5</td>
<td>50.6 ± 8.4</td>
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</tr>
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<td></td>
<td>Total (n=110)</td>
<td>64.3 ± 8.7</td>
<td>54.7 ± 8.3</td>
<td>9.6 (5.6, 13.3)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Dom=dominant, Nondom=nondominant, GH=glenohumeral, IR=internal rotation, ER=external rotation, TROM=total range of motion, flex=flexion, ° = degrees, HS=high school, <sup>b</sup> Indicates a statistically significant result ($p<0.05$)

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Table 5.7 Two-Way ANOVA for ACS 90/90 Total Body Rotation Screen

<table>
<thead>
<tr>
<th>Impairment Measure</th>
<th>Total Rotation Screen</th>
<th>Main Effect</th>
<th>Main Effect</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pass Mean ± SD</td>
<td>Fail Mean ± SD</td>
<td>Diff. (CI95%)</td>
<td>Level</td>
</tr>
<tr>
<td>Dom Thoracic Rot, °</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youth (n=30)</td>
<td>56.9 ± 7.7</td>
<td>56.8 ± 7.5</td>
<td>0.01 (-5.9, 6.1)</td>
<td></td>
</tr>
<tr>
<td>HS (n=50)</td>
<td>62.4 ± 8.2</td>
<td>53.8 ± 8.7</td>
<td>8.6 (2.4, 13.8)</td>
<td></td>
</tr>
<tr>
<td>College (n=30)</td>
<td>59.4 ± 9.2</td>
<td>47.2 ± 7.3</td>
<td>12.2 (5.4, 19.0)</td>
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</tr>
<tr>
<td>Total (n=110)</td>
<td>60.1 ± 8.4</td>
<td>52.6 ± 7.8</td>
<td></td>
<td>0.023</td>
</tr>
<tr>
<td>Nondom Thoracic Rot, °</td>
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</tr>
<tr>
<td>Youth (n=30)</td>
<td>59.9 ± 7.0</td>
<td>60.8 ± 9.2</td>
<td>-0.9 (-2.7, 6.9)</td>
<td></td>
</tr>
<tr>
<td>HS (n=50)</td>
<td>62.6 ± 7.5</td>
<td>56.4 ± 9.4</td>
<td>6.2 (0.78, 10.4)</td>
<td></td>
</tr>
<tr>
<td>College (n=30)</td>
<td>61.6 ± 8.1</td>
<td>50.1 ± 8.1</td>
<td>11.5 (2.3, 13.1)</td>
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</tr>
<tr>
<td>Total (n=110)</td>
<td>61.4 ± 7.5</td>
<td>55.7 ± 8.9</td>
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<td>0.043</td>
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<tr>
<td>Stance Hip IR, °</td>
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<tr>
<td>Youth (n=30)</td>
<td>45.3 ± 7.8</td>
<td>38.7 ± 7.8</td>
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<td></td>
</tr>
<tr>
<td>HS (n=50)</td>
<td>40.8 ± 6.5</td>
<td>36.4 ± 6.1</td>
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<td></td>
</tr>
<tr>
<td>College (n=30)</td>
<td>40.0 ± 5.9</td>
<td>36.4 ± 10.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (n=110)</td>
<td>42.2 ± 6.7</td>
<td>37.0 ± 8.2</td>
<td>5.2 (1.7, 8.5)</td>
<td>0.170</td>
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<tr>
<td>Stride Hip IR, °</td>
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<tr>
<td>Youth (n=30)</td>
<td>46.1 ± 7.8</td>
<td>39.1 ± 8.3</td>
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</tr>
<tr>
<td>HS (n=50)</td>
<td>43.5 ± 5.9</td>
<td>36.2 ± 9.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College (n=30)</td>
<td>37.2 ± 3.4</td>
<td>38.8 ± 12.5</td>
<td></td>
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</tr>
<tr>
<td>Total (n=110)</td>
<td>42.6 ± 5.7</td>
<td>38.0 ± 10.1</td>
<td>4.6 (0.61, 8.6)</td>
<td>0.282</td>
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<tr>
<td>Stance Hip ER, °</td>
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</tr>
<tr>
<td>Youth (n=30)</td>
<td>49.5 ± 6.4</td>
<td>45.5 ± 8.9</td>
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<tr>
<td>HS (n=50)</td>
<td>46.3 ± 5.6</td>
<td>42.4 ± 6.6</td>
<td></td>
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</tr>
<tr>
<td>College (n=30)</td>
<td>44.4 ± 6.1</td>
<td>42.0 ± 8.1</td>
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</tr>
<tr>
<td>Total (n=110)</td>
<td>46.1 ± 6.0</td>
<td>44.1 ± 7.9</td>
<td>2.0 (-1.0, 4.9)</td>
<td>0.089</td>
</tr>
<tr>
<td>Stride Hip ER, °</td>
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</tr>
<tr>
<td>Youth (n=30)</td>
<td>44.3 ± 7.3</td>
<td>41.4 ± 8.8</td>
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<tr>
<td>HS (n=50)</td>
<td>44.3 ± 5.7</td>
<td>40.8 ± 6.8</td>
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</tr>
<tr>
<td>College (n=30)</td>
<td>43.4 ± 4.8</td>
<td>41.1 ± 7.2</td>
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<tr>
<td>Total (n=110)</td>
<td>44.0 ± 5.9</td>
<td>41.1 ± 7.6</td>
<td>2.9 (-0.20, 5.9)</td>
<td>0.949</td>
</tr>
</tbody>
</table>

* Dom=dominant, Nondom=nondominant, IR=internal rotation, ER=external rotation, rot=rotation, ° = degrees, HS=high school

* indicates statistically significant result (p < 0.05)
Table 5.8 Two-Way ANOVA for ACS Lower Body Diagonal Reach Screen

<table>
<thead>
<tr>
<th>Impairment Measure</th>
<th>Pass</th>
<th>Fail</th>
<th>Diff. (CI95%)</th>
<th>Main Effects</th>
<th>Main Effects</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Diff. (CI95%)</td>
<td>Level</td>
<td>Screen</td>
<td>Screen*Level</td>
</tr>
<tr>
<td>Stance YBT-PL, cm</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Youth (n=30)</td>
<td>103.6 ± 5.1</td>
<td>97.5 ± 10.3</td>
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<tr>
<td>HS (n=50)</td>
<td>108.3 ± 11.0</td>
<td>99.7 ± 9.9</td>
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<td></td>
</tr>
<tr>
<td>College (n=30)</td>
<td>109.7 ± 10.3</td>
<td>102.2 ± 6.4</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Total (n=110)</td>
<td>107.2 ± 8.8</td>
<td>99.8 ± 8.9</td>
<td>7.4 (3.6, 11.2)</td>
<td>0.104</td>
<td>0.001b</td>
<td>0.860</td>
</tr>
<tr>
<td>Stride YBT-PL, cm</td>
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</tr>
<tr>
<td>Youth (n=30)</td>
<td>105.9 ± 7.6</td>
<td>99.2 ± 7.6</td>
<td></td>
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<tr>
<td>HS (n=50)</td>
<td>104.2 ± 8.8</td>
<td>98.8 ± 9.3</td>
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<tr>
<td>College (n=30)</td>
<td>107.5 ± 10.0</td>
<td>101.0 ± 5.6</td>
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<tr>
<td>Total (n=110)</td>
<td>105.9 ± 8.8</td>
<td>99.6 ± 7.5</td>
<td>6.3 (2.8, 9.8)</td>
<td>0.378</td>
<td>0.001b</td>
<td>0.920</td>
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<td>Stance Hip IR,°</td>
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</tr>
<tr>
<td>Youth (n=30)</td>
<td>43.7 ± 8.4</td>
<td>39.5 ± 8.1</td>
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<tr>
<td>HS (n=50)</td>
<td>40.2 ± 6.9</td>
<td>35.6 ± 5.3</td>
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<tr>
<td>College (n=30)</td>
<td>38.6 ± 11.1</td>
<td>36.3 ± 8.9</td>
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<tr>
<td>Total (n=110)</td>
<td>40.8 ± 8.8</td>
<td>37.1 ± 7.4</td>
<td>3.7 (0.51, 6.8)</td>
<td>0.093</td>
<td>0.023b</td>
<td>0.803</td>
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<td>Stride Hip IR,°</td>
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</tr>
<tr>
<td>Youth (n=30)</td>
<td>46.7 ± 6.0</td>
<td>38.8 ± 8.7</td>
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</tr>
<tr>
<td>HS (n=50)</td>
<td>40.1 ± 9.3</td>
<td>37.1 ± 8.7</td>
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<td></td>
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</tr>
<tr>
<td>College (n=30)</td>
<td>39.5 ± 13.0</td>
<td>37.9 ± 9.6</td>
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<tr>
<td>Total (n=110)</td>
<td>42.3 ± 9.4</td>
<td>37.6 ± 9.0</td>
<td>4.7 (0.92, 8.4)</td>
<td>0.150</td>
<td>0.015b</td>
<td>0.512</td>
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<td>Stance Hip ER,°</td>
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</tr>
<tr>
<td>Youth (n=30)</td>
<td>47.6 ± 11.2</td>
<td>46.5 ± 6.7</td>
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</tr>
<tr>
<td>HS (n=50)</td>
<td>45.0 ± 5.4</td>
<td>42.2 ± 7.2</td>
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<td></td>
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</tr>
<tr>
<td>College (n=30)</td>
<td>45.5 ± 7.2</td>
<td>42.4 ± 5.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (n=110)</td>
<td>45.6 ± 7.9</td>
<td>44.1 ± 6.4</td>
<td>1.6 (-1.2, 4.3)</td>
<td>0.112</td>
<td>0.267</td>
<td>0.443</td>
</tr>
<tr>
<td>Stride Hip ER,°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youth (n=30)</td>
<td>40.0 ± 8.6</td>
<td>43.1 ± 8.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HS (n=50)</td>
<td>43.3 ± 7.0</td>
<td>40.3 ± 5.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>College (n=30)</td>
<td>42.0 ± 6.8</td>
<td>41.3 ± 6.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (n=110)</td>
<td>42.5 ± 7.5</td>
<td>40.7 ± 6.9</td>
<td>1.8 (-1.2, 4.8)</td>
<td>0.987</td>
<td>0.230</td>
<td>0.476</td>
</tr>
</tbody>
</table>

*a YBT-PL=Y Balance Test – Posterolateral reach, IR=internal rotation, ER=external rotation, rot=rotation, ° = degrees, HS=high school

*b indicates statistically significant result (p <0.05)
CHAPTER 6. SUMMARY

The overarching purpose of this dissertation was to empower baseball coaches and healthcare providers with a field expedient screening tool to identify MSK injury risk factors in baseball players. The first purpose of this dissertation was to explore the current extent of arm care exercise program usage including program design, implementation barriers, and understanding of injury prevention measures among high school baseball coaches in the United States. The second purpose was to assess the intra-rater and inter-rater reliability of a modified field expedient Arm Care Screen (ACS) based on the principles of Functional Movement Systems in high school baseball coaches. The third purpose of this dissertation was to determine the discriminant validity of the ACS to detect baseball specific MSK injury risk factors in youth, high school, and college level baseball players.

6.1 Hypothesis and Findings Specific Aim 1 (Chapter 3)

Specific Aim 1: To investigate if high school baseball coaches are using arm care programs to promote shoulder and elbow health for their players. The primary objective was to determine if high school baseball coaches are implementing generalized group-based programs or individualized arm care designed on the specific needs of the player. The secondary objective sought to investigate if the use of arm care programs is influenced by coaches’ age, education, and experience level. Finally, potential barriers to arm care implementation and high school baseball coaches’ current awareness and beliefs associated with injury prevention were determined.
Hypothesis 1: It was hypothesized that most of the high school coaches surveyed would design non-individualized group-based arm care exercise programs which does not consider the unique physical limitations of each player.

Finding: This hypothesis was accepted as 81.4% (n=465/571) of high school baseball coaches surveyed reported using non-individualized group-based arm care exercise programs.

Hypothesis 2: It was hypothesized that older coaches with more education and experience would be more likely to implement individualized arm care exercises.

Findings: This hypothesis was partially accepted as nearly twice as many high school baseball coaches surveyed who were > 40 years old (23.1%, n=151/654) implemented individualized arm care compared to coaches who were < 40 years old (11.8%, n=77/654) (p=0.001). Furthermore, 19.8% (n=130/654) of high school coaches with greater than seven years of coaching experience implemented individualized arm care compared to only 11.6% (n=76/654) among coaches with less than six years of experience (p=0.043). However, the coaches’ obtained educational status was not associated with implementation of individualized arm care programs compared to group-based programs (p=0.467).

Among those surveyed, 22.2% (n=145/654) of high school coaches without a college degree utilized individualized arm care programs compared to 18.2% (n=119/654) of coaches with a college degree.

Hypothesis 3: It was hypothesized that limited time and staff would be the greatest barriers hindering arm care implementation.
Findings: This hypothesis are partially accepted as 41% (n=34/83) of high school coaches surveyed reported that lack of perceived benefit and 31.3% (n=26/83) of coaches implicated limited staffing as the greatest factors impeding implementation. Only 11% (n=9/83) of coaches suggested that limited time was the major reason for not implementing arm care programs.

Hypothesis 4: It was hypothesized that high school coaches will demonstrate limited knowledge of important injury risk factors in baseball players.

Findings: This hypothesis was accepted as most of the coaches surveyed reported that reduced shoulder mobility was the largest contributor (42.4%, n=277/654) followed by pitching >8 months per year (32.9%, n=215/654). Other risk factors such as throwing with a fatigued arm (16.7%, n=109/654) and playing catcher as a secondary position (2%, n=12/654) were less consistently identified as major risk factors while 27.7% (n=182/654) of coaches were “not sure” or “disagreed” that having a previous injury increased risk for a future injury.

6.2 Hypothesis and Findings Specific Aim 2 (Chapter 4)

Specific Aim 2: To establish the intra-rater and inter-rater reliability of a novel arm care screening tool in high school baseball coaches. The secondary objective of this aim was to determine if high school baseball coaches and physical therapists can expect similar scoring results on the ACS.

Hypothesis 1: The ACS will demonstrate no less than moderate intra-rater and inter-rater reliability with a Cohen’s kappa value >0.40 when administered by high school baseball coaches.
Findings: This hypothesis was accepted as high school baseball coaches demonstrated moderate to excellent intra-rater reliability and substantial to excellent inter-rater reliability among all raters for each component of the ACS. The mean Cohen’s kappa coefficient for intra-rater reliability was 0.76 (95% CI, 0.54-0.95) and percent absolute agreement ranged from 0.82-0.94 among all raters. Inter-rater reliability demonstrated a mean Cohen’s kappa value of 0.89 (95% CI, 0.77-0.99) while percent absolute agreement between raters ranged from 0.81-1.00.

Hypothesis 2: There will be no difference in ACS scoring results between high school baseball coaches with minimal experience screening movement and a physical therapist multiple years of movement screening experience.

Finding: This hypothesis was accepted as intra- and inter-rater reliability did not differ between raters with various movement screening experience ($p>0.05$).

6.3 Hypothesis and Findings Specific Aim 3 (Chapter 5)

Specific Aim 3: Investigate the discriminant validity of the ACS to detect the presence or absence of known MSK risk factors common in baseball pitchers which could lead to overuse injuries. The secondary purpose of this aim was to determine if the ACS can be utilized in youth, high school, and college level baseball players for identifying decreased ROM and balance limitations.

Hypothesis 1: It was hypothesized that poor performance on the ACS components would be highly sensitive at detecting the presence of at least one associated MSK risk factor.

Findings: This hypothesis was accepted as the results support the primary hypothesis that the ACS tests can accurately discriminate between baseball players with MSK risk factors with high sensitivity. The sensitivity of the reciprocal shoulder mobility, 90/90 total
body rotation, and LB diagonal reach screens were 0.90 (95% CI, 0.82-0.95), 0.85 (95% CI, 7.77-0.91), and 0.84 (95% CI, 0.76-0.90), respectively. MSK risk factors were two-three times more likely to be present in those who tested positive on the reciprocal shoulder mobility screen (+LR=2.03, 95% CI, 1.44-2.87), 90.90 total body rotation screen (+LR=3.09; 95% CI, 1.70-5.61), or the LB diagonal reach (+LR=2.95; 95% CI, 1.49-5.84).

**Hypothesis 2:** It was hypothesized that youth, high school, and college level baseball players who failed the ACS subtests would have lower mean impairment measures compared to those who passed regardless of age. This hypothesis was evaluated with a 3x2 analysis of variance (ANOVA) with three age levels (youth, high school, and college) and screen performance dichotomized as pass or fail.

**Findings:** This hypothesis was accepted as baseball players across all age levels who failed the subtests of the ACS demonstrated significantly lower ROM and balance values in several corresponding impairment measures compared to those who passed. The mean differences of players who passed or failed the reciprocal shoulder mobility, 90/90 total body rotation, and LB diagonal reach screens were significant for all related impairment measures except for shoulder ER PROM and hip ER PROM. All significant mean differences exceeded the minimal detectable change at the 95% level of the measures. No significant interactions effects were identified for the reciprocal shoulder mobility and LB diagonal reach screen performance and age level. The only significant interaction was between age level and the 90/90 total body rotation test screen outcome observed for dominant (p=0.036) and nondominant thoracic rotation (p=0.043). Multiple comparisons
post hoc testing showed that thoracic rotation PROM significantly differed in high school and college players based on screen performance but not among in youths.

6.4 Synthesis and Application of Results

The overarching purpose of the first study presented in chapter 3 of this dissertation was to investigate how and if high school baseball coaches are implementing arm care programs to promote arm health. The results of the survey highlight the importance of empowering the coach with innovative ways to support their injury prevention ambitions. From the perspective of the coach, the primary objective for arm care programming is to prevent injuries, but the results suggest that their injury prevention awareness is limited, and lack of confidence their program’s effectiveness coupled with staffing limitations discourage implementation. The results of those surveyed indicate that the majority of high school coaches accept the primary role of preventing baseball injuries. Moreover, 71% (n=59/83) of coaches surveyed who are not currently using arm care exercise programs are interested in using a screening tool to aid in designing a program.

High school coaches feel that they can positively impact the health and well-being of their players more effectively than healthcare providers despite their poor knowledge of injury risk factors. In conjunction with the majority of coaches using arm care programs, it appears that time is not a limiting factor. In fact, most responding coaches dedicate 10-20 minutes of practice time three times per week to arm care exercises. However, coaches and rehabilitation professionals could do a better job collaborating on risk factors and injury prevention strategies. Collaborative efforts between rehabilitation professionals and coaches are needed to provide educational opportunities for injury prevention strategies. This may include providing up to date information in a location
which is easily assessable and practically applicable for the coaches’ everyday needs.

Resources, training, and staffing limitations prevent high school coaches from performing comprehensive MSK assessments and testing on their players throughout the season to prevent injuries. Therefore, the primary purpose of the second study presented in chapter 4 of this dissertation was to establish the intra and inter-rater reliability of a field expedient arm care screening tool in high school baseball coaches. It was determined that high school baseball coaches were highly reliable at scoring the ACS. The findings of this study highlight the importance of equipping coaches with a reliable tool that can be used to monitor for decreased physical function throughout the season. High school coaches can perform the ACS in less than three minutes which is more time efficient and feasible compared to the 10-15 minutes needed to administer existing screening tools. Furthermore, minimal training (~1 hour) is required to be proficient in scoring the ACS with no additional costs or certification required to implement. Therefore, it seems reasonable to instruct baseball coaches who believe it is their responsibility to prevent injuries with a simple and reliable screening tool to determine if an athlete is starting to develop MSK impairments.

Previous research has reported that raters with more movement testing experience have better intra-rater and inter-rater reliability compared to less experienced raters. In the current study, there was no reliability differences between raters regardless of movement screening experience. It is likely that the reduced number of categorical scoring options compared to other movement screens minimized errors among the raters. By dichotomizing each component of the ACS as pass or fail, scoring complexity is reduced and the raters are better able to agree on the testing results regardless of their experience. The
ACS is a highly feasible movement screening option for implementation in the high school baseball environment and will allow coaches to quickly monitor for attenuating physical function.

While the findings of the second study suggest that the ACS is reliable, validation of the screening tool is warranted prior to mainstream use in the sport of baseball. Therefore, the third study presented in chapter 5 of this dissertation assessed the discriminability of the ACS at detecting common MSK impairments and/or risk factors. The findings of this study suggest that all three components of the ACS exhibited high sensitivity for identifying at least one corresponding MSK risk factor in baseball players. The ACS evaluates global movement patterns which are more convenient for baseball coaches to evaluate since precise goniometric measurement of local ROM throughout the body is not practical on the field. Measuring individual impairment measures required two testers to perform well and is very time consuming. Further, these impairments are likely to change throughout the season, so a reliable and valid screening tool to assess multiple impairments in less than three minutes could be beneficial.

Poor performance on the individual components of the ACS were associated with the presence of corresponding injury risk factors, thus informing targeted exercise intervention. Implementation of the ACS would allow coaches to capture players with MSK risk factors, as well as some players who were falsely positive without risk factors. Inclusion of baseball players without MSK risk factors would not be problematic in this case because additional arm care exercises will not be harmful. Baseball coaches routinely implement group-based arm care programs to maintain strength, flexibility, and prevent in-
juries. However, modification of arm care exercises may be required to adjust for the development of new impairments or risk factors as the season progresses. Resources and staffing limitations prevent high school coaches from performing comprehensive MSK assessments and testing on their players multiple times during the season. The ACS provides coaches with a tool to track changes in movement quality and decreased physical function so that exercise intervention can be recommended prior to the onset of injury.

In conclusion, major injury risk factors throughout the kinetic chain can be identified expediently with a simple screening tool which can be reliably administered by baseball coaches. Limited access to athletic trainers or strength and conditioning specialists does not have to be a barrier to implementation of meaningful and informed arm care programming. Baseball coaches possess the autonomy to screen their players for major physical limitations and risk factors which could lead to injury or performance declines. Consequently, coaches can play a larger role in injury prevention initiatives by designing and modifying their arm care programs based on objective screening results. However, exclusively considering only intrinsic risk factors or extrinsic risk factors would lack a comprehensive injury prevention approach. Future research should concurrently exam the longitudinal effects of diminishing physical function and increased throwing volume and workload with the onset of soreness or injury. Additionally, future research should investigate the effectiveness of targeted arm care exercise programming based on ACS results at reducing soreness and injury in baseball players.
APPENDICES

APPENDIX 1. Arm Care and Injury Prevention Survey

Thank you for agreeing to take part in this important survey measuring current perceptions and usage of injury prevention programs in high school baseball players. Today we are gaining your thoughts and opinions in order to better serve you and your team in the future. This survey should only take 7 minutes to complete, and participation is completely voluntary. Your participation in this survey is anonymous as we will not collect any identifying information and the information you provide will be kept confidentially. When you are ready click the “I agree” button in the lower right corner to begin. Clicking the “I agree” button indicates that your consent and agreement to complete the survey.

Block 1: Demographics

Q1 What level of team do you coach? (select all that apply)
  ○ Recreational team – (local league of team from the same general area)
  ○ School team – (affiliated with the high school)
  ○ Traveling team – (team that competes in local or regional tournaments on a regular basis)
  ○ Other (Type in the box provided) ________________

Q2 What is the age of the baseball players that you coach? (select all that apply)
  ○ < 15 years
  ○ 15-18 years
  ○ 18-22 years
  ○ > 22 years

Q3 How many years have you been involved in coaching baseball players?
  ○ < 1 year
  ○ 1-3 years
  ○ 4-6 years
  ○ 7-10 years
  ○ > 10 years

Q4 How old are you?
Q5 Please select the highest education level you have obtained?

- High school graduate/GED
- Some college
- Bachelor of Science degree
- Master’s degree
- Doctoral degree

Block 2: Arm Health

Q6 Do you currently have your baseball players perform a program to improve arm health?

- Yes
- No

Q7 Please rank on a scale of 1-5 the reasons why you don’t use an arm care program with your players. (1=biggest reason, 5= smallest reason) (Drag boxes to rank)

- Not enough time
- Not enough equipment
- Unsure of what kind of program to perform
- Don’t see the benefit of doing an arm care program
- Not enough staff to assist

Q8 What is your primary goal for having your players perform an arm care program?

- Enhance performance
- Prevent injuries
- Reduce soreness
- Maintain strength and flexibility

Q9 Which of the following best describes your arm care program?
Individualized – each player receives different exercises based on their individual limitations
Group based – I use a general program that is similar for all players

Q10 Would you be willing to perform a 3-minute screen on your players to help individualize your players’ arm care program?
  o Yes
  o No

Q11 Should pitchers participate in an exercise program to improve/maintain shoulder and elbow health?
  o Yes
  o No

Q12 Should the position players receive the same arm care program as the pitchers?
  o Yes
  o No

Q13 What do you have your baseball players do for shoulder/elbow health? (Select all that apply)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor pitch counts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrower’s Ten</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tom House Warm up exercises</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indian Clubs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pitch Smart Rest Guidelines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Flow Restriction Therapy</td>
<td></td>
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</tr>
<tr>
<td>Ice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Body Weight Training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerobic Conditioning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foam Rolling and /Soft Tissue Work to the Upper Body</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor Shoulder and Elbow Fatigue</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q14 Please indicate how many minutes per week is spent on each of the following exercises in your arm care program. (Drag the slide bar to the number of minutes spent on each exercise)

Minutes per week spent on each exercise of the arm care program

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Minutes Per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back of the shoulder stretching</td>
<td>5-6</td>
</tr>
<tr>
<td>Front of the shoulder stretching</td>
<td>4-5</td>
</tr>
<tr>
<td>Upper back stretching</td>
<td>5-6</td>
</tr>
<tr>
<td>Hip stretching</td>
<td>5-6</td>
</tr>
<tr>
<td>Shoulder strengthening</td>
<td>5-6</td>
</tr>
<tr>
<td>Neck stretching</td>
<td>5-6</td>
</tr>
<tr>
<td>Hip strengthening</td>
<td>5-6</td>
</tr>
<tr>
<td>Core strengthening</td>
<td>5-6</td>
</tr>
</tbody>
</table>

Q15 What time of year do you have your players perform your arm care program?

- Only during the preseason
- Only during the offseason
- From start of the season to the end of the season
- From preseason to end of season
- Year around

Q16 How many times per week do you have your players perform your arm care program during the off-season?

- 1x/week
- 2x/week
- 3x/week
- 4x/week
- 5x/week
- 6x/week
Q17 During the season, how many practices and games are your players participating in during a typical week?

- 1 practice or game per week
- 2 practice or game per week
- 3 practice or game per week
- 4 practice or game per week
- 5 practice or game per week
- 6 practice or game per week
- 7 practice or game per week

Q18 How many times per week do you have your players perform your arm care program during the season?

- 1x/week
- 2x/week
- 3x/week
- 4x/week
- 5x/week
- 6x/week
- 7x/week

Q19 Do your players perform the arm care program during baseball practice time?

- Yes
- No

Q20 In minutes, what is a reasonable amount of time per practice that you would be willing to dedicate to an arm care program?

- Less than 5 minutes
- 5 to 10 minutes
- 10 to 15 minutes
- 15 to 20 minutes
Q21 When do your baseball players perform the arm care program?
   - Before practice starts
   - After practice ends
   - At home on their own
   - In the training room/weight room

Q22 How many injuries have been reduced as a result of your arm care program in the last season?
   - 0
   - 1
   - 2
   - 3
   - 4
   - 5
   - 6
   - 7
   - 8
   - 9
   - 10

Block 3: Injury Prevention

Q23: Arm care programs can reduce injuries to the elbow/shoulder in high school baseball pitchers.
   - Strongly agree
   - Agree
   - Not sure
   - Disagree
   - Strongly disagree

Q24: Arm care programs can enhance performance.
   - Strongly agree
   - Agree
   - Not sure
Q25: Based on your coaching experience, please rank the following risk factors in order (1=largest contributor, 5=smallest contributor) that you feel contributes most to injuries in your baseball players. (Drag boxes to rank)

- Reduced shoulder range of motion
- Throwing with a fatigue arm
- Pitching greater than 8 months per year
- Playing catcher as a secondary position
- Decreased shoulder strength

Q26: Having a previous injury will lead to an increased risk for a future injury.

- Strongly agree
- Agree
- Not sure
- Disagree
- Strongly disagree

Q27: Deficits in the hips and/or core can contribute to injuries of the shoulder and elbow.

- Strongly agree
- Agree
- Not sure
- Disagree
- Strongly disagree

Q28: Injury risk factors should be monitored throughout the entire season.

- Strongly agree
- Agree
- Not sure
- Disagree
- Strongly disagree
Q29: Who do you feel plays the largest role in preventing baseball injuries in high school players.

- The player
- Teammates
- Coaches
- Parents
- Physicians, Physical Therapists (PT), Athletic Trainers (ATC)
APPENDIX 2. Baseball Coach Informed Consent

Baseball Coach Informed Consent to Participate in a Research Study

KEY INFORMATION FOR: DEVELOPMENT OF A FIELD EXPEDIENT BASEBALL SCREENING TOOL FOR THE COACH TO IDENTIFY MUSCULOSKELETAL IMPAIRMENTS

We are asking you (baseball coach) to choose whether or not to volunteer for a research study about developing a screening test which could be used by baseball coaches to identify common limitations in flexibility and strength. Physical limitations of the shoulder, spine, and hips have been shown to contribute to injuries in adolescent baseball players. We are asking you to participate in this study because no test currently exists which can identify physical limitations for high school baseball players. It is important to make sure that this test is reproducible among coaches and that it can detect the important physical limitations specific to high school baseball players.

This page is to give you key information to help you decide whether to participate. We have included detailed information after this page. Feel free to ask the research team questions. If you have questions later, the contact information for the research investigator in charge of the study is below.

WHAT IS THE STUDY ABOUT AND HOW LONG WILL IT LAST?

By doing this study, we hope to learn that high school baseball coaches can accurately perform three simple tests to identify physical limitations and injury risk factors. The testing results should be easy to score and accurate no matter if scored by the head or assistant coach. Poor performance on our new screening test should also identify the presence of important limitations in flexibility or strength of the shoulders, spine, and/or hips. Your participation in this research will include two 30-minute testing sessions each week for a total of four weeks.

WHAT ARE KEY REASONS YOU MIGHT CHOOSE TO VOLUNTEER FOR THIS STUDY?

You will benefit from participating in this study by learning a field expedient screening test they could be performed on your players to identify major asymmetries or limitations in shoulder, spine, or hip mobility and single leg balance deficits.

WHAT ARE KEY REASONS YOU MIGHT CHOOSE NOT TO VOLUNTEER FOR THIS STUDY?

There are no anticipated risks to you participating in this study. We will be asking you to volunteer your personal time for the research team to evaluate your reproducibility of screening the players. The research team anticipates approximately 1 hour per week for 4 weeks for your time commitment to this study. Additional time after practice may not be feasible for your current life situation.

DO YOU HAVE TO TAKE PART IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any services, benefits or rights you would normally have if you choose not to volunteer. Choosing to volunteer or not to volunteer in this study will not affect your job or your coaching obligations in anyway.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, OR CONCERNS?

If you have questions, suggestions, or concerns regarding this study or you want to withdraw from the study contact Kyle Matsel, principal investigator (PI) of the University of Kentucky, Department of Rehabilitation Sciences at kyle.matsel@uky.edu or (812) 488-5105. If you have any concerns or questions about your rights as a volunteer in this research, contact staff in the University of Kentucky (UK) Office of Research Integrity (ORI) between the business hours of 8am and 5pm EST, Monday-Friday at 859-257-9428 or toll free at 1-866-400-9428.
DETAILED CONSENT:

ARE THERE REASONS WHY YOU WOULD NOT QUALIFY FOR THIS STUDY?
In order to be included in this study, you must be a current and active coach on a men’s varsity, junior varsity, or freshman high school baseball team. You could be excluded from participation in this study if you are unwilling to learn the testing procedures, are legally blind, or are unable to read or write English.

WHERE WILL THE STUDY TAKE PLACE AND WHAT IS THE TOTAL AMOUNT OF TIME INVOLVED?
The research procedures will be conducted at your local high school outside on the baseball field. Coaches will perform the screening test on the players to evaluate their flexibility and balance one time during the study. This session will take about 30 minutes. The total amount of time you will be asked to volunteer for this study is will be approximately 1 hour per week over a 4-week period. After the coaches have tested players twice (once live and once over video recording) with a 1-week period of time in between testing sessions your commitment to this research study has ended.

WHAT WILL YOU BE ASKED TO DO?
- If you choose to participate in the study, you will be asked to perform the screening tests on all your players on two separate occasions occurring 1 week apart. The first screening session will be in person and the second screening session will occur electronically. The second session will include re-scoring a video recording of the players’ screen taken at the first session. The coach participants will not be visible in the video recording.
- The goal is to determine if our tests can be consistently scored by multiple people and if our testing can identify limitations in flexibility or balance in baseball players.
- One week from the first testing session you will be asked to review the video taken on the first day of testing of the players being screened. You will score the players on the same three movements (shoulder mobility, total body rotation, and single leg balance reach test) electronically using the video previously taken.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?
This research is not without potential risks. The types of risk or discomfort in a research study can vary depending on the nature of the study and the level of risk or discomfort can range from little to none, up to a significant amount. We do not anticipate any significant risks from participating in this research; however, it is impossible to guarantee that no risks will result from participating in the this (or any) study.
- There is no financial cost associated with participating in this study and increased emotional or psychological distress is unlikely.
- There is the unlikely risk of breach of confidentiality. Every attempt will be made to keep personal information, medical history, and testing results confidential at all times.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?
The coaches participating in this study will benefit by learning a field expedient screening tool they could perform on their players to identify major asymmetries or limitations in shoulder, spine, or hip mobility and single leg balance deficits.

IF YOU DON’T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?
If you choose not to volunteer for this study, there is no alternative testing protocol which can be offered.

WHAT WILL IT COST YOU TO PARTICIPATE?
There will be no monetary costs except for the time commitment required to participate in this study. We don’t anticipate any physical discomfort or injury to occur to you while you are conducting the screening procedures. In the rare event of an injury, treatment will be made available including first aid, emergency treatment, and follow-up care as needed. Costs for such care will be billed in the ordinary manner and at the usual charge to you or your insurance company.
You and/or your insurance company, Medicare, or Medicaid will be responsible for the costs of all care and treatment that you would normally receive for any conditions you may have. These are costs that are considered medically necessary and will be part of the care you receive even if you do not take part in this study.

The University of Kentucky may not be allowed to bill your insurance company, Medicare, or Medicaid for the medical procedures done strictly for research.

Therefore, these costs:

- will be your responsibility, or
- may be paid by your insurer if you are insured by a health insurance company (you should ask your insurer if you have any questions regarding your insurer’s willingness to pay these costs); or
- may be paid by Medicare or Medicaid if you are covered by Medicare or Medicaid. (If you have any questions regarding Medicare/Medicaid coverage you should contact Medicare by calling 1-800-Medicare (1-800-633-4227) or Medicaid at 1-800-635-2570.)

Your insurer, Medicare, or Medicaid may agree to pay for the costs. However, a co-payment or deductible may be needed from you. The amount of this co-payment or deductible may be costly.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?

When we write about or share the results from the study, we will write about the combined information. We will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. We will assign an identification number to your scores so your information will be kept separate from your personal identifying information. A list of names and numbers will be kept in a locked file and will be destroyed after the research is completed. The informed consent/assent document with your name on it will not include any information other than your name and will not be available to anyone other than the research team. All data collected will be saved and stored on a password protected computer stored at the University of Kentucky in the office of Dr. Tim Uhl 210c Wethington Building, 900 South Limestone Street, Lexington, KY. Computer records will be kept for 6 years following study completion and then destroyed according to UK Policy A13-050 and UK Policy A05-055. Project co-investigators and committee members overseeing the research may have access to the data to assist with analysis and dissemination of results.

You should know that in some cases we may have to show your information to other people.

For example, the law may require us to share your information with:

- a court or agencies, if you have a reportable disease/condition.
- authorities, if you report information about a child being abused; or if you pose a danger to yourself or someone else.

To ensure the study is conducted properly, officials of the University of Kentucky may look at or copy pertinent portions of records that identify you.

We will make every effort to safeguard your data, but as with anything online, we cannot guarantee the security of data obtained by way of the Internet. Third-party applications used in this study may have Terms of Service and Privacy policies outside of the control of the University of Kentucky.

CAN YOU CHOOSE TO WITHDRAW FROM THE STUDY EARLY?

You can choose to leave the study at any time. You will not be treated differently if you decide to stop taking part in the study.

If you choose to leave the study early, data collected until that point will remain in the study database and may not be removed.

The investigators conducting the study may need to remove you from the study. You may be removed from the study if:

- you are not able to follow the directions,
- we find that your participation in the study is more risk than benefit to you.
ARE YOU PARTICIPATING, OR CAN YOU PARTICIPATE, IN ANOTHER RESEARCH STUDY AT THE SAME TIME AS PARTICIPATING IN THIS ONE?

You may not take part in this study if you are currently involved in another research study. It is important to let the investigator/your doctor know if you are in another research study. You should discuss this with the investigator/your doctor before you agree to participate in another research study while you are in this study.

WHAT HAPPENS IF YOU GET HURT OR SICK DURING THE STUDY?

If you believe you are hurt or if you get sick because of something that is due to the study, you should call Kyle Matsel PT, DPT, SCS, CSCS (PI) at (618) 384-9535 immediately. Kyle Matsel PT, DPT, SCS, CSCS (PI) will determine what type of treatment, if any, is best for you at that time. If deemed necessary, referral to Dr. Tim Hamby (612-477-1558) the team physician and medical monitor will be recommended or in cases of an emergency calling 911 may be necessary.

It is important for you to understand that the University of Kentucky does not have funds set aside to pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. Also, the University of Kentucky will not pay for any wages you may lose if you are harmed by this study.

Medical costs related to your care and treatment because of study-related harm will be your responsibility or may be paid by your insurer if you are insured by a health insurance company (you should ask your insurer if you have any questions regarding your insurer’s willingness to pay under these circumstances, or may be paid Medicare/Medicaid if you are covered by Medicare/Medicaid (if you have any questions regarding Medicare/Medicaid coverage you should contact Medicare by calling 1-800-Medicare (1-800-633-4227) or Medicaid 1-800-635-2570).

A co-payment/deductible may be needed by your insurer or Medicare/Medicaid even if your insurer or Medicare/Medicaid has agreed to pay the costs. The amount of this co-payment/deductible may be costly.

You do not give up your legal rights by signing this form.

WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?

You will not receive any rewards or payment for taking part in the study.

WHAT IF NEW INFORMATION IS LEARNED DURING THE STUDY THAT MIGHT AFFECT YOUR DECISION TO PARTICIPATE?

We will tell you if we learn new information that could change your mind about staying in the study. We may ask you to sign a new consent form if the information is provided to you after you have joined the study.

WILL YOU BE GIVEN INDIVIDUAL RESULTS FROM THE RESEARCH TESTS?

Generally, tests done for research purposes are not meant to provide clinical information. However, we will provide you with your individual research results.

There is a slight possibility that during a research project, an investigator could discover something that could affect your health. If this occurs, the finding will be reviewed by Tim Uhl PhD, ATC, PT, FNATA and Terry Malone PT EdD, ATC, FAPTA expert consultants to determine if it is in your best interest to contact you.

Do you give permission for us to contact you about research results or incidental findings that are determined to be important to you/your family’s health? (Incidental findings are unforeseen findings discovered during the course of the research that may affect you or your family’s health).

p Yes p No ___________Initials

You may also withdraw your consent to be contacted with information about research results or incidental findings by sending a written request to Kyle Matsel (812) 488-5105 at 515 Bob Jones Way, Evansville, IN 47708.

WILL WE CONTACT YOU WITH INFORMATION ABOUT PARTICIPATING IN FUTURE STUDIES?

The research staff would like to contact you in the future with information about participating in additional studies. If so, it will be limited to 1 time per year.
Do you give your permission to be contacted in the future by Kyle Matsel PT, DPT, SCS, CSCS regarding your willingness to participate in future research studies?
O Yes   O No   Initials ________

WHAT ELSE DO YOU NEED TO KNOW?
If you volunteer to take part in this study, you will be one of about 2 people to do so.
The principal investigator, Kyle Matsel, is a PhD doctoral student at the University of Kentucky. He is being guided in this research by Tim Uhl, PhD, ATC, PT. There may be other people on the research team assisting at different times during the study.
The information that you are providing will no longer belong to you. The research may lead to new clinical or educational knowledge, tests, treatments, or products. These products could have some financial value. There are no plans to provide financial payment to you or your relatives if this occurs.

WILL YOUR INFORMATION BE USED FOR FUTURE RESEARCH?
All identifiable information (e.g., your name, medical record number, or date of birth) will be removed from the information collected in this study. This means that no link or code to your identity will be kept. After all identifiers have been removed, the information may be used for future research or shared with other researchers without your additional informed consent. Once you give your permission to have your de-identified information stored, they will be available indefinitely and cannot be removed due to the inability to identify them.
INFORMED CONSENT SIGNATURES

You have read the above information and have received answers to any questions you asked. You consent to take part in the study. You are aware that information gained from your participation in this study may be published in medical literature, discussed for educational purposes, and used generally in the furtherance of medical science. You also understand that by participating in this investigational study, you will not be personally identified.

This consent includes the following:

- Key Information Page
- Detailed Consent
- Appendix 1. Arm Care Screen Testing Procedures

You will receive a copy of this consent form after it has been signed.

<table>
<thead>
<tr>
<th>Signature of research subject or, if applicable</th>
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<tr>
<td>*research subject’s legal representative</td>
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<th>Printed name of research subject</th>
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<tr>
<th>Printed name of [authorized] person obtaining informed consent</th>
<th>Date</th>
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8
APPENDIX 3. Parental Permission and Informed Consent

Parental Permission/Consent to Participate in a Research Study

KEY INFORMATION FOR: DEVELOPMENT OF A FIELD EXPEDIENT BASEBALL SCREENING TOOL FOR THE COACH TO IDENTIFY MUSCULOSKELETAL IMPAIRMENTS

We are asking you (parent of minor player, or an adult player) to choose whether or not to volunteer for a research study about developing a screening test which could be used by baseball coaches to identify common limitations in flexibility and strength. Physical limitations of the shoulder, spine, and hips have been shown to contribute to injuries in adolescent baseball players. We are asking you to participate in this study because no test current exists which can identify physical limitations for high school baseball players. It is important to make sure that this test is reproducible among coaches and that it can detect the important physical limitations specific to high school baseball players. If you are a parent: when we say “you” in this consent form, we mean “your child; “we” means the doctors/researchers and other staff.

This page is to give you key information to help you decide whether to participate. We have included detailed information after this page. Feel free to ask the research team questions. If you have questions later, the contact information for the research investigator in charge of the study is below.

WHAT IS THE STUDY ABOUT AND HOW LONG WILL IT LAST?

By doing this study, we hope to learn that high school baseball coaches can accurately perform three simple tests to identify physical limitations and injury risk factors. The testing results should be easy to score and accurate no matter if scored by the head or assistant coach. Poor performance on our new screening test should also identify the presence of important limitations in flexibility or strength of the shoulders, spine, and/or hips. Your participation in this study will include 1 session lasting 30 minutes.

WHAT ARE KEY REASONS YOU MIGHT CHOOSE TO VOLUNTEER FOR THIS STUDY?

You will benefit from being included in this study by learning if they have any limitations or asymmetries in your movement patterns and/or the presence of important physical impairments/risk factors which could increase potential for injury.

WHAT ARE KEY REASONS YOU MIGHT CHOOSE NOT TO VOLUNTEER FOR THIS STUDY?

There are minimal risks to participating in this study. It is possible that the testing procedures may result in temporary mild muscular soreness. This soreness is typical with engagement in any form a physical exercise or sport and usually only lasts 24-48 hours. It is unlikely that soreness will be severe enough to alter activities of daily life or participation in sports. Secondly, we will be videotaping you performing the testing procedure. You may not wish to be videotaped because your face will be visible in the video recording.

If you choose not to volunteer for this study, after the data has been collected the players will be provided an individual summary report of their results. The summary report will indicate areas where the player was limited or if specific injury risk factors were present. General exercise recommendations will be provided to the participants to improve the limitations identified by the testing.

DO YOU HAVE TO TAKE PART IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any services, benefits or rights you would normally have if you choose not to volunteer. Choosing to volunteer or not to volunteer in this study will not affect your baseball status, position, playing time, or other baseball related decisions made between you and your coach.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS OR CONCERNS?

If you have questions, suggestions, or concerns regarding this study or you want to withdraw from the study contact Kyle Matsel, principal investigator (PI) of the University of Kentucky, Department of Rehabilitation Sciences at kyle.matsel@uky.edu or (812) 488-5105. If you have any concerns or questions about your rights as a volunteer in this research, contact staff in the University of Kentucky (UK) Office of Research Integrity (ORI) between the business hours of 8am and 5pm EST, Monday-Friday at 859-257-9428 or toll free at 1-866-400-9428.
DETAILED CONSENT:

ARE THERE REASONS WHY YOU WOULD NOT QUALIFY FOR THIS STUDY?
In order to be included in this study, you must be a current and active player on a men's varsity, junior varsity, or freshman high school baseball team. You could be excluded from participation in this study if you are under the age of 14 years, have had a concussion or vestibular issued within the last month, undergone surgery in the last 3 months, are unable to participate in general exercise or sport due to a current or previous injury, or unable to read and/or write English.

WHERE WILL THE STUDY TAKE PLACE AND WHAT IS THE TOTAL AMOUNT OF TIME INVOLVED?
The research procedures will be conducted at your local high school outside on the baseball field. Coaches will perform the screening test on you to evaluate your flexibility and balance one time during the study. This session will take about 30 minutes. Your total commitment time to the study will be about 30 minutes.

WHAT WILL YOU BE ASKED TO DO?

- If you choose to participate in the study you will be asked to allow the research team and/or your coach to test the flexibility of your shoulders, spine, and hips and measure your single leg balance. While you are being tested a member of the research team will be video recording your performance. Your face will be visible in the recording. This is for the coaches to review and score your performance after 1 week to make sure the scoring is consistent. Your face will not be blurred out when later reviewed by the coaches and researchers.

- Previous research has shown that flexibility limitations and poor balance could increase risk for injury in baseball players, but it is unknown if out movement testing will be able to identify those specific limitations.
  - On the first day of testing you will be asked to fill out a questionnaire providing information related to your height, weight, age, and relevant medical history. You will then be asked to perform three movements including: 1) shoulder mobility test, 2) total body rotation test, and 3) single leg balance reach test. Two coaches and primary investigator will watch you perform these tests and score your performances independently. You will be asked if any of the tests cause physical pain. Completion of these three tests should only take about 2 minutes to perform. (Appendix 1: Arm Care Screen Testing Procedures//Illustration)
  - Additionally, you will be asked to have your shoulder, spine, and hip flexibility and your lower body balance measured by a physical therapist. These measurements will include shoulder rotation and overhead range of motion, upper back rotation, hip rotation range of motion, and the Y Balance Test. See Appendix 2 for details related to each specific measurement. This portion of the testing will take approximately 15 minutes to complete.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?
This research is not without potential risks. The types of risk or discomfort in a research study can vary depending on the nature of the study and the level of risk or discomfort can range from little to none, up to a significant amount. We do not anticipate any significant risks from participating in this research; however, it is impossible to guarantee that no risks will result from participating in the this (or any) study.

- Since the testing requires full range of motion of some joints, it is reasonably expected that you could experience some minor soreness that should last no more than 48 hours. It is unlikely that soreness will be severe enough to alter activities of daily life or participation in sports.
- Sustaining a physical injury which would result in loss of time from sport or medical consultation is unlikely.
- In the event that any research-related activities result in a physical injury, treatment will be made available including first aid, emergency treatment, and follow-up care as needed. The participant's parent/guardian will be contacted immediately.
- There is no financial cost associated with participating in this study and increased emotional or psychological distress is unlikely.
- There is the unlikely risk of breach of confidentiality. Every attempt will be made to keep personal information, medical history, and testing results confidential at all times.
There is always a chance that any medical treatment can harm you. The research procedures in this study are no different. In addition to risks described in this consent, you may experience a previously unknown risk or side effect.

**WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?**

You will benefit from being included in this study by learning if you have any limitations or asymmetries in their movement patterns and/or the presence of important physical impairments/risk factors which could increase potential for injury. After the data has been collected, you will be provided an individual summary report of their results. The summary report will indicate areas of the player was limited or if specific injury risk factors were present. General exercise recommendations will be provided to the participants to improve the limitations identified by the testing.

**IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?**

If you choose not to volunteer for this study, there is no alternative testing protocol which can be offered.

**WHAT WILL IT COST YOU TO PARTICIPATE?**

There will be no monetary cost required to participate in this study. As a result of participating in the study, you may experience mild muscle soreness which could last up to two days. Delayed onset muscle soreness is common among those who exercise and play sports and should not affect activities of daily life or sport participation. In the rare event of an injury, treatment will be made available including first aid, emergency treatment, and follow-up care as needed. Costs for such care will be billed in the ordinary manner and at the usual charge to you or your insurance company.

You and/or your insurance company, Medicare, or Medicaid will be responsible for the costs of all care and treatment that you would normally receive for any conditions you may have. These are costs that are considered medically necessary and will be part of the care you receive even if you do not take part in this study.

The University of Kentucky may not be allowed to bill your insurance company, Medicare, or Medicaid for the medical procedures done strictly for research.

Therefore, these costs:

- will be your responsibility, or
- may be paid by your insurer if you are insured by a health insurance company (you should ask your insurer if you have any questions regarding your insurer’s willingness to pay these costs); or
- may be paid by Medicare or Medicaid if you are covered by Medicare or Medicaid. (If you have any questions regarding Medicare/Medicaid coverage you should contact Medicare by calling 1-800-Medicare (1-800-633-4227) or Medicaid at 1-800-635-2570.)

Your insurer, Medicare, or Medicaid may agree to pay for the costs. However, a co-payment or deductible may be needed from you. The amount of this co-payment or deductible may be costly.

**WHO WILL SEE THE INFORMATION THAT YOU GIVE?**

When we write about or share the results from the study, we will write about the combined information. We will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. We will assign an identification number to your scores so your information will be kept separate from your personal identifying information. A list of names and numbers will be kept in a locked file and will be destroyed after the research is completed. The informed consent/assent document with your name on it will not include any information other than your name and will not be available to anyone other than the research team. All data collected will be saved and stored on a password protected computer stored at the University of Kentucky in the office of Dr. Tim Uhl 210c Wethington Building, 900 South Limestone Street, Lexington, KY. Computer records will be kept for 6 years following study completion and then destroyed according to UK Policy A13-050 and UK Policy A05-055. Project co-investigators and committee members overseeing the research may have access to the data to assist with analysis and dissemination of results.
You should know that in some cases we may have to show your information to other people.

For example, the law may require us to share your information with:

- a court or agencies, if you have a reportable disease/condition;
- authorities, if you report information about a child being abused; or if you pose a danger to yourself or someone else.

To ensure the study is conducted properly, officials of the University of Kentucky may look at or copy pertinent portions of records that identify you.

We will make every effort to safeguard your data, but as with anything online, we cannot guarantee the security of data obtained by way of the Internet. Your face will be visible on the video recording of the coaches conducting the screening. However, only the PI and the coaches will review these recordings. All video recordings will identifiable features will be erased immediately following the conclusion of the study. Third-party applications used in this study may have Terms of Service and Privacy policies outside of the control of the University of Kentucky.

**CAN YOU CHOOSE TO WITHDRAW FROM THE STUDY EARLY?**

You can choose to leave the study at any time. You will not be treated differently if you decide to stop taking part in the study.

If you choose to leave the study early, data collected until that point will remain in the study database and may not be removed.

The investigators conducting the study may need to remove you from the study. You may be removed from the study if:

- you are not able to follow the directions,
- we find that your participation in the study is more risk than benefit to you.

**ARE YOU PARTICIPATING, OR CAN YOU PARTICIPATE, IN ANOTHER RESEARCH STUDY AT THE SAME TIME AS PARTICIPATING IN THIS ONE?**

You may not take part in this study if you are currently involved in another research study. It is important to let the investigator/your doctor know if you are in another research study. You should discuss this with the investigator/your doctor before you agree to participate in another research study while you are in this study.

**WHAT HAPPENS IF YOU GET HURT OR SICK DURING THE STUDY?**

If you believe you are hurt or if you get sick because of something that is due to the study, you should call Kyle Matsel PT, DPT, SCS, CSCS (PI) at (618) 384-9535 immediately. Kyle Matsel PT, DPT, SCS, CSCS (PI) will determine what type of treatment, if any, is best for you at that time. If deemed necessary, referral to Dr. Tim Hambly (812-477-1558) the team physician and medical monitor will be recommended or in cases of an emergency calling 911 may be necessary.

It is important for you to understand that the University of Kentucky does not have funds set aside to pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. Also, the University of Kentucky will not pay for any wages you may lose if you are harmed by this study.

Medical costs related to your care and treatment because of study-related harm will be your responsibility or may be paid by your insurer if you are insured by a health insurance company (you should ask your insurer if you have any questions regarding your insurer’s willingness to pay under these circumstances, or may be paid Medicare/Medicaid if you are covered by Medicare/Medicaid (if you have any questions regarding Medicare/Medicaid coverage you should contact Medicare by calling 1-800-Medicare (1-800-633-4227) or Medicaid 1-800-635-2570).

A co-payment/deductible may be needed by your insurer or Medicare/Medicaid even if your insurer or Medicare/Medicaid has agreed to pay the costs. The amount of this co-payment/deductible may be costly.

You do not give up your legal rights by signing this form.

**WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?**

You will not receive any rewards or payment for taking part in the study.
WHAT IF NEW INFORMATION IS LEARNED DURING THE STUDY THAT MIGHT AFFECT YOUR DECISION TO PARTICIPATE?
We will tell you if we learn new information that could change your mind about staying in the study. We may ask you to sign a new consent form if the information is provided to you after you have joined the study.

WILL YOU BE GIVEN INDIVIDUAL RESULTS FROM THE RESEARCH TESTS?
Generally, tests done for research purposes are not meant to provide clinical information. However, we will provide you with your individual research results.

There is a slight possibility that during a research project, an investigator could discover something that could affect your health. If this occurs, the finding will be reviewed by Tim Uhl, PhD, ATC, PT, FNATA and Terry Malone, PT EdD, ATC, FAPTA expert consultants to determine if it is in your best interest to contact you.

Do you give permission for us to contact you about research results or incidental findings that are determined to be important to you or your family’s health? (Incidental findings are unforeseen findings discovered during the course of the research that may affect you or your family’s health).

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<th>Yes</th>
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<th>Initials</th>
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You may also withdraw your consent to be contacted with information about research results or incidental findings by sending a written request to Kyle Matsel (812) 488-5105 at 515 Bob Jones Way, Evansville, IN 47708.

WILL WE CONTACT YOU WITH INFORMATION ABOUT PARTICIPATING IN FUTURE STUDIES?
The research staff would like to contact you in the future with information about participating in additional studies. If so, it will be limited to 1 time per year.

Do you give your permission to be contacted in the future by Kyle Matsel, PT, DPT, SCS, CSCS regarding your willingness to participate in future research studies?

| O Yes | O No | Initials |_______ |

WHAT ELSE DO YOU NEED TO KNOW?
If you volunteer to take part in this study, you will be one of about 28 people to do so.

The principal investigator, Kyle Matsel, is a PhD doctoral student at the University of Kentucky. He is being guided in this research by Tim Uhl, PhD, ATC, PT. There may be other people on the research team assisting at different times during the study.

The information that you are providing will no longer belong to you. The research may lead to new clinical or educational knowledge, tests, treatments, or products. These products could have some financial value. There are no plans to provide financial payment to you or your relatives if this occurs.

WILL YOUR INFORMATION BE USED FOR FUTURE RESEARCH?
All identifiable information (e.g., your name, medical record number, or date of birth) will be removed from the information collected in this study. This means that no link or code to your identity will be kept. Your face will be visible on the video recordings and will not be de-identified during data collection. Immediately following data collection completion, the videos containing your face will be deleted. After all identifiers have been removed, the information may be used for future research or shared with other researchers without your additional informed consent. Once you give your permission to have your de-identified information stored, they will be available indefinitely and cannot be removed due to the inability to identify them.
**INFORMED CONSENT SIGNATURES**

You have read the above information and have received answers to any questions you asked. You consent to take part in the study. You are aware that information gained from your participation in this study may be published in medical literature, discussed for educational purposes, and used generally in the furtherance of medical science. You also understand that by participating in this investigational study, you will not be personally identified.

This consent includes the following:

- Key Information Page
- Detailed Consent
- Appendix 1. Arm Care Screen Testing Procedures
- Appendix 2. Musculoskeletal Impairment Measurements

You will receive a copy of this consent form after it has been signed.

<table>
<thead>
<tr>
<th>Signature of research subject or, if applicable,</th>
<th>Date</th>
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<td>*research subject’s legal representative</td>
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Printed name of research subject

*Printed name of research subject’s legal representative

*If applicable, please explain Representative’s relationship to subject and include a description of representative’s authority to act on behalf of subject:

Printed name of [authorized] person obtaining informed consent | Date

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University of Kentucky
Revised 03/27/20

Med IRB ICF Template Combined with HIPAA Authorization

Page 9 of 9
You are invited to be in a research study being done by Kyle Matsel from the University of Kentucky. Research studies are done when doctors want to find new ways of helping people. You are invited because you are a current high school baseball player.

You will be asked questions about your height, weight, age, and medical history. You will then be asked to perform three movement tests including: 1) shoulder mobility test, 2) total body rotation test, and 3) single leg forward reach test. Two of your coaches and Kyle Matsel will watch you perform these tests and score your performance. You will be asked if any of the tests cause physical pain. Completion of these three tests should only take about 2 minutes to perform. Your performance will be video recorded for the testers to review 1 week later.

If you choose to participate in the study you will be asked to allow the research team and/or your coach to test the flexibility of your shoulders, back, and hips and measure your single leg balance. While you are being tested a member of the research team will be video recording your performance. This is for the coaches to review and rescore your performance after 1 week to see if the scoring is similar. Additionally, you will be asked to have the flexibility of your shoulders, back, and hips and your balance measured by a research assistant. These measurements will only be taken once and will only take about 10 minutes to complete.

Sometimes these tests may cause minor muscle soreness. This soreness is common with exercise or sport and usually only lasts 1-2 days. It is unlikely that soreness will be bad enough limited your daily activity or participation in sports.

Your family and your coach will know that you are in the study. If anyone else is given information about you, they will not know your name. A number or initials will be used instead of your name.

You will not receive any rewards or payment for taking part in the study.

If something makes you feel bad while you are in the study, please tell Kyle Matsel or your parent. If you decide at any time you do not want to finish the study, you may stop whenever you want.

You can ask Kyle Matsel, your coach, or the study assistants questions any time about anything in this study. You can also ask your parent(s) any questions you might have about the study.

Signing this paper means that you have read this document, or had it read to you and that you want to be in the study. If you do not want to be in the study, do not sign the paper. Being in the study is up to you, and no one will be mad if you do not sign this paper or even if you change your mind later. You agree that you have been told about this study and why it is being done and what to do.
Signature of Person Agreeing to be in the Study

Name of (Authorized) Person Obtaining Informed Assent

Signature of Principal Investigator or Sub/Co-Investigator
University of Kentucky
Revised 5/17/17

F1.0200
Medical Research Assent Document
APPENDIX 5. Data Collection Form – Demographics and Medical History

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<td>Height: in</td>
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<td>Age:</td>
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<td>Gender: M / F</td>
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<td>School:</td>
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<th>Sports Participation</th>
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<tr>
<td>Year in School (circle one)</td>
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<tr>
<td>5th grade</td>
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<tr>
<td>High School Freshman</td>
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<td>College Freshman</td>
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<table>
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<tr>
<th>How many years have you played baseball?</th>
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<td>Primary Position: Secondary Position:</td>
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<tr>
<th>Do you pitch?</th>
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<tr>
<td>Yes</td>
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1. Are you currently injured or recovering from an injury?  
   Yes | No
   If yes:  
   Right  Left  
   Body Location: 

2. Do you currently have or are you undergoing treatment for a head cold, sinus infection, ear infection or balance disorder?  
   Yes | No

3. Have you had a concussion or head injury in the past three (3) months?  
   Yes | No
APPENDIX 6. Data Collection Form – Arm Care Screen Scoring

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<tr>
<th>Tester:</th>
<th>Trial _____</th>
<th>ID #</th>
</tr>
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<tbody>
<tr>
<td>Arm Care Screen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>Left</td>
<td></td>
</tr>
<tr>
<td>Shoulder Mobility (Open Fist)</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>90/90 Total Body Rotation</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>Lower Body Diagonal Reach</td>
<td>Pass</td>
<td>Fail</td>
</tr>
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</tbody>
</table>
## APPENDIX 7. Data Collection Form – Impairment Measurements

### Lower Quarter Y Balance Test

<table>
<thead>
<tr>
<th>Direction</th>
<th>Right (cm)</th>
<th>Left (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterolateral</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Musculoskeletal Impairments

<table>
<thead>
<tr>
<th>Right (degrees)</th>
<th>Left (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GH Internal Rotation PROM</td>
<td></td>
</tr>
<tr>
<td>GH External Rotation PROM</td>
<td></td>
</tr>
<tr>
<td>GH Flexion PROM</td>
<td></td>
</tr>
<tr>
<td>Thoracic Rotation PROM</td>
<td></td>
</tr>
<tr>
<td>Prone Hip Internal Rotation PROM</td>
<td></td>
</tr>
<tr>
<td>Prone Hip External Rotation PROM</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 8. Arm Care Screen Procedures and Scoring Criteria

The Arm Care Screen includes 3 movement patterns which require shoulder, spine, and hip mobility and dynamic single leg balance.

**Reciprocal Shoulder Mobility Screen**

**Description/Purpose:** Dysfunction in the shoulder and thoracic spine can place increased stress on the shoulder and increase risk for injury. The Reciprocal Shoulder Mobility screen evaluates for limited shoulder and thoracic spine range of motion. Hypermobility of the shoulders can lead to overuse injury as can hypomobility. The major dysfunctions which could limit the Reciprocal Shoulder Mobility screen includes poor shoulder flexion, extension, internal rotation, and external rotation range of motion and/or thoracic extension mobility.

**Testing Procedure:** The Reciprocal Shoulder Mobility screen is evaluated with the athlete standing feet together with both hands open and simultaneously reaches one hand behind their head and other hand behind and up their back, assuming an extended and internally rotated position with one shoulder and a flexed and externally rotated position with the other. During the test the arms should move in one smooth motion and tall posture should be maintained while the athlete attempts to touch the fingertips of both hands together. The test is repeated on the opposite side.

Starting Position

Testing the Left Side

Testing the Right Side

**Passing Criteria:**

- Ability to touch fingertips together in a one smooth motion without loss of posture

**Failing Criteria:**

- Inability to touch fingertips together with hands open
- Loss of upright posture during the movement

**Tips for Testing:**

- Make sure the athlete does not try to walk their hands toward each other following initial contact.
- The athlete should maintain upright posture – watch for side bending or forward bending of the torso.

**90/90 Total Body Rotation Screen**
Description/Purpose: The ability to rotate through the hips and torso is important for rotational sports such as baseball. The 90/90 Total Body Rotation screen evaluates for normal spine and hip rotational ability. The major dysfunctions which could limit the 90/90 Total Body Rotation screen includes poor range of motion in hip internal rotation, hip external rotation, and/or thoracic spine rotation. With the arms in the 90/90 position the shoulder blades are placed in a retracted and depressed position and limits the shoulders is ability to compensate as the body rotates.

Testing Procedure: The athlete assumes a standing position with feet together, toes pointing forward and arms in the 90/90 position (90° shoulder abduction and 90° elbow flexion). The athlete then rotates the entire body including the hips, shoulders, and head as far as possible to the right while the foot position remains unchanged. Have the athlete return to the starting position and repeat the test on the left.

<table>
<thead>
<tr>
<th>Starting Position</th>
<th>Testing the Right Side</th>
<th>Testing the Left Side</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Starting Position" /></td>
<td><img src="image2" alt="Testing the Right Side" /></td>
<td><img src="image3" alt="Testing the Left Side" /></td>
</tr>
</tbody>
</table>

Scoring: The 90/90 Total Body Rotation screen is scored as Pass or Fail on both the right and left sides. The side being scored is the direction which the athlete is rotating toward. To Pass the screen, the athlete must meet the passing criteria on both sides. For example, a score of Pass on the right and a score of a Fail on the left would result in an overall score of Fail for this test.

Passing Criteria:

- Ability to see the front of the opposite shoulder while viewing the movement from behind the athlete

Failing Criteria:

- Inability to see the front of the opposite shoulder
- Inability to maintain upright posture (sidebending)
- Inability to maintain arms in the 90/90 starting position

Tips for Testing:

- Best viewed from behind the athlete
- Make sure the feet remain straight ahead and together
- Watch for excessive effort or perceived exertion – the movement should be smooth

Inability to see front of opposite shoulder
**Lower Body Diagonal Reach Screen**

**Description/Purpose:** Baseball is a dynamic sport which requires stability and balance in lower body. The Lower Body Diagonal Reach screen will challenge the athlete’s dynamic balance as they approach their limits of stability. The major dysfunctions which could affect performance on the Lower Body Diagonal Reach test includes limited hip rotational mobility and/or poor balance.

**Testing Procedure:** To perform the Lower Body Diagonal Reach screen the athlete starts by standing with feet together and toes touching a wall. Step back away from the wall 1-shoe length by moving the right foot back so that the right toes are even with the left heel. Then bring the left foot back so that the left toes are even with the right heel so that your toes are 2-shoe lengths away from the wall. Then bring your feet together and turn to your left by pivoting on your right foot so you are perpendicular to the wall.

<table>
<thead>
<tr>
<th></th>
<th>Start</th>
<th>1-shoe length</th>
<th>2-shoe lengths</th>
<th>2-shoe lengths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1.png" alt="Start" /></td>
<td><img src="image2.png" alt="1-shoe length" /></td>
<td><img src="image3.png" alt="2-shoe lengths" /></td>
<td><img src="image4.png" alt="2-shoe lengths" /></td>
</tr>
</tbody>
</table>

Keeping the right foot flat on the ground and your left foot hovering just above the floor and try to touch the wall where it meets the floor with your left toes. Perform 3 consecutive reaches at 2-shoe lengths as a warm-up. Following the warm-up, perform 5 consecutive reaches 2-shoe lengths from the wall attempting to touch toes to the wall each time without your foot touching down or losing balance. Then switch sides and repeat the test with your right foot reaching.

<table>
<thead>
<tr>
<th></th>
<th>Starting Position</th>
<th>Testing the Right Side</th>
<th>Testing the Left Side</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image5.png" alt="Starting Position" /></td>
<td><img src="image6.png" alt="Testing the Right Side" /></td>
<td><img src="image7.png" alt="Testing the Left Side" /></td>
</tr>
</tbody>
</table>

**Scoring:** The Lower Body Diagonal Reach screen is scored as *Pass* or *Fail* on both the right and left sides. The side being scored is named for the leg balancing on the ground, not for the reaching leg. To Pass the test, the athlete must meet the passing criteria on both sides.

**Passing Criteria:**

- Ability to touch the wall just above where the floor and wall meet standing 2-shoe lengths away 5 consecutive times and return to staring position without losing balance or touching foot down.
**Failing Criteria:**

- Inability to touch the wall 2-shoe lengths away 5 consecutive times without loss of balance
- The heel of the stance leg lifts off the ground

**Tips for Testing:**

- The athlete must touch the wall 5 times while maintain single leg balance the entire time
  – they cannot touch their foot down in between reaches
- Remeasure 2-shoes lengths from the wall prior to testing the opposite side
REFERENCES


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VITA

Kyle A. Matsel PT, DPT, SCS, CSCS

EDUCATION:

Institution: University of Evansville
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Duration of Study: June 2008 – May 2011
Field of Study: Physical Therapy
Degree: Doctor of Physical Therapy

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Location: Evansville, Indiana
Duration of Study: August 2004 – May 2008
Field of Study: Exercise Science
Degree: Bachelor of Science

Licensure Information:
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State of Indiana
License Number: #05010551A
July 2011 - Present

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ProRehab/University of Evansville Sports Physical Therapy Residency
Duration: July 2011 – October 2012

Certifications:
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   American Board of Physical Therapy Specialties
   Certification Number: #43682
   June 2013 – Present

2. Certified Strength and Conditioning Specialist (CSCS)
   National Strength and Conditioning Association
   Certification Number: #200835732
   June 2008 – Present

EMPLOYEMENT

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Rank: Assistant Professor
Tenure Status: Non-Tenured, Tenure Track
Sports Residency: Director Sports Residency Program, May 2020 - Present
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Location: Evansville, Indiana
Duration: August 2016 to Present, Adjunct Faculty 2014 - 2015
Title/Position: Physical Therapist  
  Rank: Staff Physical Therapist  
  Facility: ProRehab, PC  
  Location: Evansville, Indiana  
  Duration: July 2011 - Present

Title/Position: Adjunct Faculty  
  Rank: Adjunct Faculty  
  Institution: Rocky Mountain University of Health Professions  
  Location: Provo, Utah  
  Duration: January 2015 – Present

Title/Position: Continuing Education Instructor/Assistant Fellowship Director  
  Rank: Instructor  
  Company: Functional Movement Systems  
  Duration: January 2013 – Present

Peer Reviewed Scientific Publications


Grantsmanship


Professional Poster Presentations


4. Bullock GS, Plisky PJ, Matsel KA, Weaver A, Gourlay J, Kiesel KB. The Relationship Between the Half Kneeling Ankle Dorsiflexion and A Novel Weight Bearing Lunge Tests. Poster presentation at the American College of Sports Medicine (ACSM); Minneapolis, MN May 2018


Books and Chapters


Invited Presentations

National Presentation:


6. Cook G, Matsel KA. “To Hack or Not to Hack” Perform Better Conference
• Long Beach, CA. August 2016
• Providence, RI. July 2016
• Chicago, IL. June 2016


Local and Regional Presentation:

1. Matsel KA. “Youth Baseball Injury Prevention Considerations” Virtual Webinar, Evansville, IN March 2021

2. Matsel KA. "Systematic Discharge Testing” Vincennes University” Vincennes, IN, April 2018


Honors and Awards:

Mary Bennett Outstanding Professor of the Year 2021 University of Evansville DPT Program
Mary Bennett Outstanding Professor of the Year 2020 University of Evansville DPT Program
Mary Bennett Outstanding Professor of the Year 2019 University of Evansville DPT Program