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Aaron D. Sciascia

University of Kentucky, aaron.sciascia@eku.edu

Author ORCID Identifier:

 <http://orcid.org/0000-0002-5518-4615>

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Aaron D. Sciascia, Student

Dr. Timothy L. Uhl, Major Professor

Dr. Esther Dupont-Versteegden, Director of Graduate Studies

PROSPECTIVE ASSESSMENT OF RETURN TO PRE-INJURED LEVELS OF
ACTIVITY

DISSERTATION

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

By

Aaron D. Sciascia

Lexington, Kentucky

Co-Directors: Dr. Timothy L. Uhl, Professor of Athletic Training and Dr.
Arthur J. Nitz, Professor of Physical Therapy

Lexington, Kentucky

2016

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ABSTRACT OF DISSERTATION

PROSPECTIVE ASSESSMENT OF RETURN TO PRE-INJURED LEVELS OF ACTIVITY

Determining return to pre-injured levels of play following athletic injury can be challenging. The current practice of making decisions following rehabilitation as to whether or not a patient has returned to pre-injured levels of activity is potentially inaccurate because initial assessments of perceived physical capability are performed at a time of relative dysfunction or are based on patient recall. Since there is no true baseline of perceived and physical function prior to injury it is difficult to determine if an athlete has return to baseline or is simply better than they were at the time of injury. Therefore, it is unclear whether a true link can be established between rehabilitation and the restoration of pre-injured physical function. Therefore, the purpose of this dissertation was to obtain values of perceived and demonstrable physical function in collegiate prior to the occurrence of injury and following rehabilitation to determine if physical function was restored prior to permitting the athletes to return to activity.

Patient opinion about the ability to perform athletic maneuvers is important following injury; however, prospective assessment of self-perceived physical function for athletes prior to the beginning of a season before injury occurrence is lacking. Baseline values of self-reported physical function relative to the perceived state of the knee, shoulder, and elbow in a wide array of athletes before the commencement of injury exposure were obtained. It was determined that 1) overall, collegiate athletes report upper level scores on selected knee, shoulder, and elbow outcome questionnaires and 2) athletes with previous injury to these joints have perceived lower physical function prior to a competitive season although they were medically cleared to participate in sport.

Previous reports have noted that the closed kinetic chain upper extremity stability test (CKCUEST) and traditional strength testing maneuvers have excellent test/re-test reliability in asymptomatic individuals but no information existed for individuals with shoulder symptoms. Therefore, subjects with and without current shoulder symptoms were recruited to determine if the CKCUEST and traditional strength testing maneuvers had similar reliability and if the CKCUEST could distinguish between persons with and without shoulder symptoms. Using traditional strength measures and the CKCUEST did not reveal meaningful differences although there was a trend towards a difference with the CKCUEST. This area certainly needs further study to identify functional measures of

strength specific to the upper extremity.

The findings from the first and second study guided me to the primary purpose of this dissertation which was to assess perceived and demonstrable physical function in collegiate athletes in a longitudinal manner in order to trace the natural history of physical function from a pre-injured time point to a post-injured time point. It was determined that not all athletes perceive their physical function as restored to baseline levels when discharged from rehabilitation to return to sport. Additionally, previous injury history negatively affects perceived physical function at both baseline and post-rehabilitation time points for persons who previously sustained a knee injury but not persons who previously sustained an ankle injury. Demonstrable physical function was not back to baseline at time of discharge but was restored within 1 month after return to activity was permitted and was not affected by a previous injury history with this sample of subjects.

KEYWORDS: Pre-injured levels of activity, return to play or activity,
self-reported physical function, physical performance measurements,
rehabilitation process

Aaron D. Sciascia

November 11, 2016

Date

PROSPECTIVE ASSESSMENT OF RETURN TO PRE-INJURED LEVELS OF
ACTIVITY

By

Aaron D. Sciascia

Timothy L. Uhl, Ph.D.

Co-Director of Dissertation

Arthur J. Nitz, Ph.D.

Co-Director of Dissertation

Esther E. Dupont-Versteegden, Ph.D.

Director of Graduate Studies

November 11, 2016

Date

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Chapter One: Introduction

Background

Injury exposure and occurrence rates in athletics have been compiled for various levels of competition with the most comprehensive collection of epidemiological athletic injury data being centered on collegiate athletes. The National Collegiate Athletic Association (NCAA) Injury Surveillance System captured approximately 182,000 injuries out of 1,000,000 exposures during a 16 year span¹. This equated to 11,000 injuries per year. Conversely, a 1 year study of high school athlete injury rates reported an occurrence of 4,350 injuries in 9 sports at 100 participating high schools². When extrapolated out to include all high schools in the United States, the annual injury occurrence would be over 1.4 million injuries². The number of participating institutions in the NCAA study was not reported so it is difficult to interpret the reported injury rates across all institutions and is likely contributing to the discrepancy in the number and type of reported injuries between the high school and collegiate levels. However, both reports identified that at least 75% of all injuries occurred to the upper and lower extremities (shoulder, knee, and ankle) with sprains and strains being the most common diagnoses^{1,2}. A time loss of 1-3 weeks for these non-operative injuries suggests that rehabilitation clinicians need to be well-versed in injury assessment and treatment as well as in understanding the factors that can influence return to play decisions for athletes trying to return to sport participation following musculoskeletal rehabilitation.

Return to activity, return to play, or return to sport are terms which describe the return to collegiate athletics following rehabilitation of a musculoskeletal injury. Return to play (RTP) assumes the patient has overcome the injury and can safely participate in

sporting activities³ thus restoring some level of physical function. Physical function is defined as one's ability to carry out activities that require physical actions, ranging from self-care (activities of daily living) to more complex activities that require a combination of skills, often within a social context (National Institute of Health Patient Reported Outcome Measurement Information System)⁴. In athletics, physical function would include an individual's ability to perform skills such as running, jumping, pivoting, throwing, and hitting as well as other sport-specific maneuvers. A number of factors have been previously proposed as potential influences that could affect successful RTP if not accounted for. These factors include medical factors (history of injury, severity of injury, symptoms, etc.), risk of re-injury (type of sport, position, level of competition), and external factors (third party influences, post-season qualification, desire to compete, etc.)³. Additionally, factors such as patient compliance to rehabilitation protocols, patient expectation, selection of RTP metrics, and the manner in which RTP is assessed in the clinical setting can also impact the return to play outcome⁵⁻⁹.

Clinicians can attempt to control for these factors in order to reduce potential deleterious consequences on achieving successful RTP as a result of overlooking their impact. For example, it is the clinician's responsibility to be knowledgeable in physiological healing and to account for tissue restoration at the cellular level during rehabilitation. Applying too little or too much stress to healing tissue at the incorrect time in the healing process can negatively affect the post-injury outcome thus inhibiting successful return to activity¹⁰⁻¹². Similarly, part of a comprehensive rehabilitation plan requires 1) patients and clinicians to set realistic attainable goals that meet the individual patient's needs while accounting for the severity of injury and 2) patients serving as

active participants in their recovery i.e. being compliant with supervised rehabilitation and home exercise programs and/or modifying activities which could aggravate or disrupt the healing process¹³⁻¹⁵. If either requirement is not adhered to, RTP may not be achieved. Finally, beyond the application of therapeutic interventions, clinicians must assess if the patient is physically capable of performing his or her sporting activities through maneuvers and tasks (known as physical performance measures⁵) designed to mimic the demands of each athlete's respective sport^{5,16,17}. Of concern is that there are numerous physical performance measures for both upper and lower extremities but none have been universally accepted as the primary means of gauging readiness to return to activity following the completion of musculoskeletal rehabilitation for specific injuries¹⁶⁻²⁵. Complicating matters further, physical performance measures are typically employed at the end of rehabilitation yet few maneuvers have been shown to have the ability to discriminate between patients with and without injury or impairment²⁶⁻²⁸ while no maneuvers have been able to show readiness to return to sport following specific types of reconstructive surgery²³.

Furthermore, the common goal for rehabilitation clinicians (certified athletic trainers, occupational therapists, and physical therapists) is to not only return a patient to activity, but to return a patient to activity levels which were similar, if not identical, to the levels which occurred prior to injury. This has been specifically highlighted in the orthopedic literature²⁹. A recent systematic review focusing on pre-injured RTP following superior labral repair (both isolated repair and repair with concurrent soft tissue debridement) found that RTP to pre-injured levels was inconsistent for overhead and non-overhead athletes however the non-overhead athletes had at least 2x greater odds of

returning to full activity compared to the overhead athletes²⁹. Despite identifying a difference in RTP between distinct groups of athletes, the review revealed an overwhelming lack of prospective data collection related to athletic performance and playing status as well as a lack of reporting of these same factors in the postoperative data. Detection, recall, and selection bias were the most common types of bias present within the studies likely due to the retrospective case series design of the studies reviewed. Outcome measures were rarely employed prospectively while the assessors who performed follow-up examinations were not blinded to the intervention thus creating the possibility of detection bias. All individuals were verbally asked at postsurgical follow-up if they had returned to their pre-injury level of play, which subjected the responses to recall bias and individual patient perception likely due to postsurgical follow-up occurring between 1–10 years. Selection bias was also evident due to a lack of matching or stratification. Considering the aim of returning an athlete to pre-injured levels of participation is a routine goal established between patients and treating clinicians, the ability to perform prior to injury is not often assessed as shown in the systematic review thus, it is unknown if return to pre-injured levels of play have or truly do occur. Therefore, the question of “did the athlete return to pre-injured levels of play” should be preceded by “how could the athlete perform before the occurrence of injury?”.

Screening athletes prior to the beginning of an athletic season currently occurs however the purpose is not for establishing performance baselines to be used later but instead for medical qualification to participate in physical activities. A pre-participation physical examination (PPE) is a comprehensive screening mechanism constructed of a battery of tests including but not limited to examinations of previous injury history,

vision, vital signs, and musculoskeletal integrity³⁰. A key aspect of the PPE is that it serves as a screening tool to identify underlying deficits which could lead to injury rather than establish a diagnosis. In other words, an athlete does not usually attend a PPE seeking a diagnosis for an existing condition thus the expectation of receiving a diagnosis of tissue derangement or other identified anatomical lesion is minimal³¹. Conversely, following the occurrence of injury, clinicians will disseminate the findings from the application of similar examination techniques utilized in a PPE to provide a specific diagnosis as part of the initial injury examination. This so called impairment testing has been shown to be helpful in identifying physical deficiencies at the beginning of rehabilitation and in determining improvement or success in non-operative and post-operative clinical scenarios throughout and following rehabilitation^{14,32-35}. On the other end of the continuum, (at the conclusion of rehabilitation following injury), a derivation of both the PPE and initial injury examination comprised of impairment testing, physical performance measures, or a combination of both may be employed in order to determine if musculoskeletal injury and/or impairment has resolved to where an athlete is ready for RTP^{3,36}. However, recent literature has noted that the evaluation process, from the PPE to the RTP assessment, is characterized by primary reliance on the findings of physical maneuvers with little mention of pertinent subjective factors such as information provided by the individual patient^{5,13,37,38}. The consequence of relying primarily on demonstrable tasks or static measures (i.e. the impairment measures such as range of motion or manual muscle testing) to make clinical decisions, especially RTP decisions which have many influential factors that could affect the outcome, is that the patient's perception on his or her readiness to participate is not considered. This lack of attention

to the patient's opinion of his or her ability to perform physical tasks is counter-intuitive to the concept of individualized care.

One of the methods of incorporating the patient's perception regarding his or her own physical function is through the use of patient-reported outcome measures (PROs). PROs are questionnaires routinely administered in a healthcare setting as the means for capturing patient perceived ability to perform daily tasks³⁹⁻⁴⁸ and in some cases challenging activities such as those performed in sports⁴⁹⁻⁵¹. Utilizing information provided by a patient is not novel as subjective information provided by a patient comprises the history portion of examinations, serving as the means to provide context for injuries and previous experiences. For example, a recent cross-sectional study obtained prospective outcomes scores for incoming military cadets with and without a history of knee ligament injury⁵⁰. The researchers found that individuals with a history of knee ligament injury had lower scores (0-12 point difference in median value) versus those who did not have an injury history per the Knee Injury and Osteoarthritis Outcome Score⁵⁰, although all individuals were medically cleared to participate in physical activities. Other investigations have shown other active groups with a history of injury to also have lower outcome scores and increased symptoms both prior to and following the commencement of physical activity^{52,53}. These studies have helped to identify a potential relationship between the occurrence of a previous injury and current lower perceived physical function after supposed injury resolution. These findings suggest that it cannot be assumed that although athletic individuals may "pass" a pre-participation physical examination, their perception of their ability to perform athletic tasks may be lower than assumed.

The intent of PROs is to incorporate the patient's perspective regarding the ability to perform activities in the context of disability, dysfunction, or impairment^{37,54} which in turn allows the clinician to treat the patient rather than the disease⁵⁵. However, the traditional medical model, which tends to focus on the disease rather than the person, has come under scrutiny because not all persons are affected similarly by a disease or condition. In an effort to individualize healthcare, impairment and disability models were developed because they attempt to put the disease in context to the individual rather than assuming all persons are affected similarly by a disease.⁵⁵⁻⁵⁹. The most widely accepted disability model is known as the International Classification of Functioning, Disability, and Health (ICF)⁵⁵. The ICF model identifies 3 primary components which may or may not be interrelated in affecting an individual's ability to perform a relative task. The 3 components include: body structure and function (anatomical and physiological systems), activity (task execution), and participation (involvement in a life situation). When attempting to describe disability, negative results contributed to the body structure component are classified as impairments such as pain, weakness, or inflexibility. Activity (physical function) limitations refer to the difficulties of executing a task such as an individual's ability to walk, run, or perform overhead tasks such as reaching a high shelf or throwing a ball. Participation restrictions describe the inability of person to complete or fulfill a societal or social role i.e. playing time on a sports team being eliminated as a result of an injury or condition. While the ICF excels at providing a framework for putting the impact of a disease in context to a single person, it has limited ability for assisting clinicians in developing rehabilitation programs for patients with musculoskeletal injury. Thus a model that could identify areas which could positively

affect the rehabilitation outcome and guide clinicians on creating treatment programs based on the identified areas of physical deficiency specific to an individual patient is needed.

Taken individually, clinical maneuvers or PROs provide useful but limited information regarding physical function as each assessment method only provides a portion of information to be utilized when designing rehabilitation programs. With the understanding that a comprehensive approach to evaluation and rehabilitation may yield more complete patient specific information which ultimately could lead to improved rehabilitation outcomes, a conceptual model describing multiple factors that influence a rehabilitation outcome was developed⁶⁰ which details 3 specific components (patient factors, clinician factors, and external factors) that should be addressed during the rehabilitation of musculoskeletal injury (Figure 1).

The Optimal Outcome Model⁶⁰ expands on the concepts contained within the ICF model as it allows clinicians to address areas of needed improvement for a single patient while attempting to achieve balance amongst the many rehabilitation related factors. A safe zone was designed to accommodate the flexibility needed in clinical rehabilitation as some patients require greater attention in one particular area over another. It is hypothesized that as long as the outcome remains within the borders of the model (the safe zone), then the outcome should be satisfactory. The model helps to illustrate that it is the responsibility of the clinician to begin the rehabilitation process by putting the condition in context to the individual patient while adding in complementary pieces such as clinical and external factors in order to create balance amongst the influential factors to achieve the best possible outcome. Measuring patient-perceived physical function *prior*

to the beginning of treatment may help limit possible strains on one or more of the components by providing insight to each individual patient's specific concerns and potential goals. To better illustrate a balanced rehabilitation model, consider the following case: An overhead athlete who has complaints of shoulder pain and decreases in throwing performance reports to his clinician for evaluation where it is determined that he has a labral injury. The evaluation reveals that he also has evident impairments of hip abductor weakness, internal rotation deficit of his dominant arm, and scapular dyskinesis. Due to the presence of these physical findings as well as the decrease in performance, the clinician recommends that the athlete enter formal rehabilitation. The athlete and his coach are concerned about how long he will be out of activity due to the injury. To create a balanced rehabilitation process and subsequently an optimal outcome, the clinician needs to satisfactorily account for all components involved with this scenario. This includes measuring the athlete's perceived pain/function and establishing attainable goals for recovery (patient component), addressing all physical impairments deemed to contribute to the athlete's dysfunction (clinician component) and communicating frequently and effectively with the athlete's coach about the rehabilitation plan and periodic progress (external factors component). A successful outcome would be achieved if all components were optimized. It is theorized that a direct relationship between component optimization and successful outcome exists⁶⁰. When specific components have not been considered or addressed, the outcome would, in theory, be suboptimal. However, it should be understood that an optimal outcome would be relative to each patient and should be interpreted in that manner.

This same comprehensive, multi-faceted approach could be applied to the PPE

and RTP assessments for an athlete. However, the effectiveness of this approach would be enhanced by obtaining information prior to injury to serve as baseline comparators in the event injury occurs in the future. This would be similar to head injury assessment models which attempt to establish physical and cognitive function prior to the occurrence of a head injury^{61,62}. Traditionally, clinical and self-reported measures of physical capability are obtained at initial evaluation following injury and periodically throughout treatment to determine if progress is occurring. Ultimately, a final set of measurements helps determine if an appropriate amount of change occurred from initial evaluation to the cessation of rehabilitation in order for the clinician to make the decision to discharge the patient from care and RTP. For example, using the hypothetical case described previously of the overhead athlete with a labral injury, the athlete is administered a shoulder-specific PRO to complete with the score, on a scale of 0-100 (low to high function), equaling a 30. After 3 weeks of treatment, the patient completes the same PRO, this time scoring an 80, with all impairments from the initial injury evaluation resolved. The change of 50 points towards higher function and the elimination of the impairments lead the treating clinician to discharge the patient from care. However, the amount of change on the PRO, while rather large, is based on an initial measurement obtained at a time of dysfunction. It is unknown if the patient's actual pre-injured ability was greater than 80. Thus, the lack of a pre-injury assessment of physical function suggests that the goal of obtaining return to pre-injured activity levels has been at best assumed or based on less than concrete information²⁹. This manner of assessment and reporting highlights a prominent gap in the literature that there is a lack of prospective information collected or utilized prior to the occurrence of injury and throughout the

rehab continuum as the continuum technically begins prior to the injury occurring^{29,60}.

Additionally, the absence of pre-injured physical function information is not the only concern for practicing clinicians but also the absence of a standardized assessment method that could be utilized both prior to injury and following injury (i.e. the RTP time period). Physical performance maneuvers and metrics utilized for determining RTP are many^{16,17,19-22,26,27,63-68} with no “best” test(s) described for the upper extremity and a limited number routinely advocated for the lower extremity²⁵⁻²⁷. The lack of a “best” test for the upper extremity is likely due to the variation in the demands of different sports on the upper extremity. For example, the demands of an American football lineman require both closed and open chain arm movements which differ from the demands on a quarterback who is required to perform primarily open chain movements with the overhead throwing motion. Due to the absence of a gold standard of assessment for upper extremity physical performance, clinicians will often utilize some variation of strength testing as the post-intervention metric because strength is a basic physiological component of physical task performance permitting fundamental tasks to be executed (such is the rationale for routinely conducting manual muscle testing procedures during clinical examinations and throughout rehabilitation)⁶⁹. As important as strength testing is for identifying potential impairments and assessing progress in the secure rehabilitation setting, it has been recognized that single component physiological measurements of strength, mobility, endurance, or pain do not necessarily translate to a patient’s ability to perform a highly skilled dynamic task^{13,16}. It is unknown if rehabilitation efforts are achieving relative restoration of physical function that existed prior to injury occurrence. The possibility exists that specific measures of physical function obtained at a pre-injured

time period may provide adequate information for clinicians to avoid premature discharge from treatment and possibly limit the potential for unnecessary additional or re-injury following RTP^{70,71}. However, it would be helpful to identify a test with acceptable reliability values which could be employed across a variety of athletes and could discern between those with and without active symptoms.

Problem

Determining return to pre-injured levels of play following athletic injury can be challenging. The existing literature reports variable rates of return to pre-injured activity levels however critical review of that same literature has revealed a prominent gap in that baseline measures of pre-injured levels of activity, either perceived or demonstrable, have not been obtained²⁹. The current practice of making decisions following rehabilitation as to whether or not a patient has returned to pre-injured levels of activity is potentially inaccurate because initial assessments of perceived physical capability are performed at a time of relative dysfunction and/or are based on patient recall. While current clinical practice can show positive change in perceived and demonstrated physical function throughout the rehabilitation continuum, it is reasonable to postulate that the documented change may not have reached actual baseline levels. Therefore; since there is no true baseline of relative, pre-injured physical function, it is unclear whether it can truly be stated that pre-injured physical function has been restored following rehabilitation.

Furthermore, clinical practice has primarily focused on making pre-participation activity decisions, injury diagnoses, and return to play decisions utilizing impairment-based maneuvers and physical performance measures aimed at identifying the existence of physical deficits. Exclusively focusing on anatomy and physiology while not

incorporating patient perception as part of the evaluation and treatment process is contrary to the individualized care model that modern healthcare strives to follow. As such, it is reasonable to theorize that a framework such as the Optimal Outcome Model which accounts for multiple influences in the evaluation and treatment process could be utilized to increase the occurrence of positive treatment outcomes.

There are 3 aspects to consider that should be addressed: 1) It is unknown how collegiate athletes with or without a history of injury, perceive his or her ability to physically perform athletic tasks prior to the beginning of a season; 2) It is unknown if physical performance measures designed to assess upper extremity physical function can be performed reliably and can distinguish between individuals with and without shoulder symptoms; and 3) It is unknown if athletes return to pre-injured levels of activity following rehabilitation when using subjective and objective measures obtained during pre-season physical examinations rather than measures obtained during initial injury evaluation.

Purpose and Aims

A goal of this proposal is to quantify physical function both before injury and after rehabilitation in order to build evidence-based guidelines for discharge/RTP as a means of developing better quantification methods for establishing better epidemiological data. The achievement of this goal would lead to the reduction and/or elimination of premature discharge from rehabilitation which would in turn reduce the re-injury risk and additional healthcare cost for further treatment. Additionally, a large heterogeneous sample will be used comprised of both male and female athletes from various sports and collegiate institutions improving the external validity of proposal. The anticipated

findings could be extrapolated beyond the ramifications for the shoulder, knee, and ankle joints. This model could be utilized for other body parts and conditions, making the rehabilitation decision making process more valid, as most of the existing evidence is based on expert opinion and it is unclear whether the behavior of the target population (collegiate athletes) reported by the experts is actually the behavior of the target population.

Specific Aim 1: Determine if self-perceived ability to physically function in athletes is impacted similarly in athletes with and without a history of injury. The primary outcome will be the amount of difference between the PRO scores between athletes with and without an injury history.

Hypothesis: Athletes with a history of injury will have a significantly lower level of perceived physical function compared to athletes without a history of injury prior to the beginning of a competitive sports season.

Specific Aim 2: To establish the reliability of traditional upper extremity strength testing and a physical performance measure for the upper extremity in persons with and without shoulder symptoms as well as to determine if the testing maneuvers could discriminate between individuals with and without shoulder symptoms.

Hypotheses: 1) The strength testing and the physical performance measure would have excellent test/re-test reliability for both testing groups, and 2) Asymptomatic individuals will demonstrate better performance on the physical performance measure than symptomatic individuals.

Specific Aim 3: Determine if athletes return to baseline values of physical function when RTP is permitted. The primary outcome will be the amount of difference between the

pre-season and discharge measurements. The secondary aim was to determine if history of injury affects perceived and demonstrable physical function at the return to activity time period.

Hypotheses: 1) Athletes that return to sport following an injury will not have a significantly lower level of physical function compared to their pre-season baseline level of physical function, and 2) Athletes with a history of injury will have significantly lower perceived and demonstrable physical function scores throughout the injury process compared to athletes without a history of injury.

Clinical Implications

The value of this protocol is found in the novelty of the prospective obtainment of upper and lower extremity testing measures during a pre-injured time period. The anticipated findings can be extrapolated beyond the ramifications for the specific anatomical joints examined in this study. This model can be utilized for other body parts and conditions for multiple individuals (athletic and non-athletic persons), making the rehabilitation decision making process more externally valid. Prospective collection is imperative to the return to sport decision making process as it allows comparisons to be made from pre-injury through post-treatment time periods. The comprehensive approach as described by the Optimal Outcome Model accounts for patient perception of physical function, objective clinical parameters and measurable performance parameters thus addressing many facets of the recovery process. The prospective design also reduces the possibility of subjective recall bias while allowing for use of real-time normative values for all measurements specific to an individual patient. It also allows clinicians to set rehabilitation and recovery goals based on actual pre-injured measures which would

improve the clinical decision-making process by eliminating the presumptive nature of current return to activity process.

Operational Definitions

Physical Function⁴: The ability to perform physical tasks such as walking, running, throwing, hitting, etc.

Subjective Physical Function: Self-perceived ability to perform athletic maneuvers such as throwing, running, cutting, maneuvering, etc. as determined by responses provided by individual participants on patient-reported outcomes questionnaires validated for athletes.

Objective Physical Function: The demonstrated ability of an individual to perform dynamic tasks (arm elevation, knee extension, etc.) and athletic maneuvers (throwing, running, cutting, maneuvering, etc.) which can be quantitatively measured and recorded.

Pre-Injured Physical Function: The level of either self-reported or demonstrated physical function during the pre-participation physical examination recorded prior to the first practice of the competitive season.

History of Injury⁷²: Any previous event a participant can recall where he or she personally defines as a known occurrence resulting in negative sensations of pain and/or tissue injury to the shoulder, knee, or ankle. Neither medical evaluation nor missed time from activity had to occur for the event to be considered an injury.

Current Injury⁷²: An event resulting in pain and/or suspected tissue damage within the musculoskeletal system requiring the individual to seek medical consultation for a diagnoses and/or treatment and missed at least 1 day of organized team activities (practice and/or game).

Assumptions

1. All baseline measures will be collected during the pre-participation physical examination
2. Subjects will give their best effort during data collection.
3. Subjects will understand the Kerlan Jobe Orthopaedic Clinic Shoulder and Elbow Score, Knee Osteoarthritis and Orthopedic Injury Score, and Foot and Ankle Disability Index and will provide answers that reflect their current level of pain and disability to the best of their ability.
4. Athletes medically cleared to participate in sport may have underlying physical deficits that could lead to injury.

Delimitations

1. The efficacy of rehabilitation performed will not be assessed.
2. Injury diagnoses will result from clinical examinations with or without diagnostic imaging.
3. Clinical diagnoses will be provided by 10 athletic trainers with varying years of clinical experience.
4. All follow-up assessments will occur within 5 days of the pre-established follow-up time periods.
5. All rehabilitation will be performed by a certified athletic trainer or physical therapist with knowledge treating musculoskeletal athletic injuries.

Limitations

1. Athletes may sustain an injury during the competitive season but may not report to the athletic training staff for evaluation.

2. The athletic training may unintentionally fail to contact the research team when an injury occurs
3. History of injury, although defined, may be perceived differently by individual athletes based on previous experiences.

Chapter Two: Review of Literature

Purpose

The purpose of this literature review is to: 1) discuss the incidence of injury in athletics and the effect of injury on physical function; 2) discuss the applicability of using patient-reported outcomes in athletes and the objective methods of measuring physical function in athletes; 3) present a theoretical model for addressing physical function to improve rehabilitation outcomes; and 4) discuss the need for improvement within the return to play process.

Injury in Athletics

Injury exposure and occurrence rates in athletics have been compiled for various levels of competition with the most comprehensive collection of epidemiological athletic injury data being centered on collegiate athletes. The National Collegiate Athletic Association (NCAA) Injury Surveillance System captured approximately 182,000 injuries out of 1,000,000 exposures during a 16 year span¹. This equated to 11,000 injuries per year. Conversely, a 1 year study of high school athlete injury rates reported an occurrence of 4,350 injuries in 9 sports at 100 participating high schools². When extrapolated out to include all high schools in the United States, the annual injury occurrence would be over 1.4 million injuries². The number of participating institutions in the NCAA study was not reported so it is difficult to interpret the reported injury rates across all institutions and is likely contributing to the discrepancy in the number and type of reported injuries between the high school and collegiate levels. However, a report from outside of the United States of America has noted similar injury occurrences amongst both collegiate and high schooled aged athletes across and within multiple

sports. Jacobsson et al⁷³ reported a high injury incidence (68%) for various sports among both adult (mean age 24 years) and youth (mean age 17 years) elite-level Swedish athletes which highlights a cross-cultural similarity in injury occurrence.

While the reported high injury occurrences in athletics include many sports for both male and female athletes, there are specific characteristics about the occurrence of injury in athletics to highlight. First, the literature continually supports that the areas of the body most affected by injury in sport are the upper and lower extremities with approximately 75% of all injuries occurring to these body regions^{1,2}. However, more than half of the extremity injuries (54-70%) occur to the lower extremity^{1,2,73-75}. Even in overhead athletics such as baseball, softball, and tennis, at least 1/3 of all injuries have been reported to occur to the lower extremity⁷⁶⁻⁷⁸. Second, injury occurrences differ based on the location of activity (practice or game) with more injuries occurring in games^{1,74-77,79-81}. While this may be somewhat of a surprise due to having more injury exposures in practices compared to games (i.e. athletes practice more than they play games), it is not completely off-base to find higher injury occurrences in game situations as it is expected that athletes participate in games with greater intensity and effort than in practice situations. However, recent evidence has identified training load as another factor affecting injury occurrence. Jacobsson et al⁷³ did not find an association between injury rate and hours or sessions trained but did note a tendency towards increased injury with the combination of hours and training intensity. In other words, practicing more often does not by itself lead to more injury but practicing at a high intensity more often can result in more injury occurrences. Third, the vast majority of injuries that occur in athletics have been described as non-traumatic or “overuse” injury with $\geq 70-90\%$ of all

injuries being classified as lacking a traumatic episode^{73,82,83}. These same sources note that a time loss of 1-3 weeks is typical for these types of injuries. Finally, a history of injury is routinely reported as a risk factor for sustaining a future injury. Murphy et al provided a comprehensive literature review of the risk factors for sustaining a lower extremity injury concluding there is strong evidence supporting the occurrence of previous injury and inadequate rehabilitation of the previous event as risk factors for future injurious episodes⁸⁴. More recent evidence has identified that males who sustain a severe injury (defined as time loss >21 days) during the previous competitive season, have a significantly greater risk of sustaining a new injury the following season⁷³. A similar phenomenon has been reported by multiple authors with the recurrence of hamstring muscle injuries following an initial primary episode^{70,85,86} as well as the increased incidence of subsequent dislocations of the shoulder following a primary dislocation⁸⁷⁻⁹².

Taken collectively, these epidemiological characteristics provide clinicians with some understanding and expectation about injury occurrence in athletics. However, there is less understanding about the impact of athletic injury on the individual athlete's ability to meet the demands of his or her sport following the injurious event (the ability to physically function in sport) and how clinicians could assess the impact of injury during medical evaluations.

Injury and its Effect on Physical Function

Function is a global term which encompasses all aspects of an individual's or population's ability to execute tasks in isolation or in society⁵⁵. While it is understood that human function is comprised of multiple facets (physical, emotional, psychosocial,

etc.), this review will focus exclusively on the physical aspect which will be termed “physical function”⁴. Physical function is defined as one's ability to carry out activities that require physical actions, ranging from self-care (activities of daily living) to more complex activities that require a combination of skills, often within a social context (National Institute of Health Patient Reported Outcome Measurement Information System)⁴. In athletics, physical function would include an individual's ability to perform skills such as running, jumping, pivoting, throwing, and hitting as well as other sport-specific maneuvers.

Physical function can be positively or negatively impacted by various factors, with negative results being termed disablement. Various disablement models have been developed to assist clinicians and practitioners in identifying how an individual's current health is affected by the presence of injury or impairment⁵⁵⁻⁵⁹. In other words, disablement models attempt to put the disease in context to the individual rather than assuming all persons are affected similarly by a disease. The most widely accepted disablement model is known as the International Classification of Functioning, Disability, and Health (ICF)⁵⁵. The ICF model identifies 3 primary components which may or may not be interrelated in affecting an individual's ability to perform a relative task. The 3 components include: body structure and function (anatomical and physiological systems), activity (task execution), and participation (involvement in a life situation). When attempting to describe disability, negative results contained within the body structure component are classified as impairments such as pain, weakness, or inflexibility. Activity (physical function) limitations refer to the difficulties of executing a task such as an individual's inability to walk or run following a knee injury, or the inability to perform

overhead tasks such as reaching a high shelf or throwing a ball following a shoulder injury. Participation restrictions describe the inability of person to complete or fulfill a societal or social role i.e. playing time on a sports team being reduced as a result of an injury or condition. The ICF model has been suggested to be clinically applicable to the musculoskeletal rehabilitation setting because it allows certified athletic trainers, occupational therapists, and physical therapists who routinely evaluate and treat musculoskeletal injuries, to place the impact of injury in context to an individual patient^{56,59}. Athletic injury can affect the components of the ICF (body structure and function, activity, and participation) differently.

First, optimized physiology (body structure and function) is presumed to be required not only for the execution of required tasks but also to decrease the risk of injury⁹³ where an optimized system reduces injury risk through increased resiliency i.e. optimized muscle flexibility decreases the risk of sustaining a muscle strain because the muscle can be taken through a greater range before deleterious effects occur. Therefore in the context of optimized physical function, physiological components such as muscular strength, endurance, and flexibility in addition to cardiovascular aerobic and anaerobic capacity are encouraged to be optimized in order to maximize performance and reduce injury. Clinicians tend to focus on identifying impairments as potential causes for injury and for years have equated deviations in anatomy and physiology to the resultant complaint of pain or dysfunction. However, the difficulty is not in identifying or treating an anatomical or physiological deficit but in recognizing the impact of the deficit on the individual's ability to physically perform a desired task.

Second, another aspect of the impact of injury on physical function is the

recurrence of injury (limitation of activity) once an athlete has been released to participate in sports following an initial injury. Surprisingly, there are limited reports on the occurrence of re-injury in athletics. Swenson et al described the rate of recurrent injury as 11% of all injuries that occurred in a 3 year period in high school athletics⁹⁴. The majority of re-injuries occurred to the ankle (28%), knee (17%), head/face (12%), and shoulder (12%)⁹⁴. Of concern however was that re-injury resulted in a greater number of athletes choosing to end sport participation. Rauh et al found the risk of re-injury to the shoulder to be greatest in high school softball (34%) and volleyball (18%) players while re-injuries to the knee was greater than the occurrence of new injuries in all sports (except soccer)⁹⁵. However, a subsequent injury to a new body part occurred more often than a re-injury to the same body part. De Visser et al noted that 14-63% of hamstring re-injuries will occur within 2 years after the initial episode⁹⁶ while De Vos et al identified clinical risk factors for sustaining a hamstring re-injury after return to activity was permitted following an initial injury episode (previous injury, active knee flexion deficit, decreased isometric knee flexion deficit at 15° flexion, and hamstring point tenderness)⁷¹. Finally, Nadler et al reported a significantly slower response time on a 20 meter shuttle run in freshman collegiate athletes with a history of lower extremity injury compared to athletes without a history of injury⁹⁷. These reports suggest that physical function, even if treated, will likely be negatively affected following the occurrence of a primary injury. It is unknown as to the manner of treatment the subjects from these separate reports received. Critical aspects such as frequency, duration, and intensity of rehabilitation were not reported nor were the methods by which an athlete was deemed ready to return to sport. Therefore, it is difficult to discern if an athlete was returned to

sport prior to the complete resolution of dysfunction/deficits in physical function and thus could not perform the activity as he or she could before the injury occurred.

Finally, some groups have reported a negative impact on psychological function following an athletic injury. Multiple studies centered on post-surgical anterior cruciate ligament (ACL) reconstruction outcomes suggest fear of re-injury may be responsible for poor return to activity rates (in the absence of significant knee impairments), indicating the presence of psychologically mediated factors for some patients⁹⁸⁻¹⁰⁰. The concept of injury having a negative psychological impact on an athlete is not novel as previous reports have noted some athletes to experience varying levels of psychological distress following injury (limitation of participation)^{101,102}. However, a recent report noted that injury can indeed result in altered negative psychological states for athletes, although athletic individuals primarily view injury occurrence as having minor consequences on daily life and emotions¹⁰³. Taken together, these reports suggest that athletes are quite similar to other non-athletic persons where injury can have deleterious consequences on psychological states but, just as is the case in the variation in perception of pain in individual persons¹⁰⁴⁻¹⁰⁶, the magnitude of the impact of the injury will vary between individuals.

The ICF model allows clinicians to view subjective physical function through the lens of the patient assisting in the identification and development of patient-specific goals for rehabilitation. This advantage complements a recognized paradigm shift in modern day healthcare where a transition from a biomedical focus highlighted by experts (i.e. clinicians) controlling the information collected and disseminated for clinical decision making, to the social focus where the patient is an active participant in the decision

making process¹⁰⁷. Traditionally, physical impairments (weaknesses, inflexibilities, muscle imbalances, etc) were determined to be resolved primarily through standard clinical measures (manual muscle testing, goniometric measurements, and visual inspection) with clinicians considering an injury to be successfully rehabilitated strictly on the improvement or resolution of the impairments. Conversely, patients may not be concerned with obtaining a specific amount of range of motion or the ability to generate an acceptable amount of force on a muscle test but instead define rehabilitation as successful when their ability to perform their job or sport at levels prior to injury¹⁰⁸ has been restored. This discrepancy in the definition of successful rehabilitation between patients and clinicians has been noted in previous work where patients did not feel rehabilitation was successful although they had improvement or resolution of impairments as determined through isolated clinical measures^{109,110}. Other factors may affect a patient's perception of rehabilitation being unsuccessful including psychosocial causes¹¹¹, unrealistic expectations¹¹², or the relationship with the clinician being taxed¹¹³. As such, obtaining the patient's perception as to how well he or she personally views the ability to perform physical tasks may be pivotal to obtaining a successful rehabilitation outcome.

PROs and Athletic Training

One of the common methods of incorporating the patient's perception regarding his or her own ability to physically function is through the use of patient-reported outcome measures (PROs). PROs are questionnaires routinely administered in a healthcare setting as the means for capturing patient perceived ability to perform daily tasks³⁹⁻⁴⁸ and in some cases challenging activities such as those performed in sports⁴⁹⁻⁵¹. The usage of

patient self-reported outcomes tools in clinical orthopedic and rehabilitation settings is common practice. However, the utilization of PROs for assessing perceived physical function in athletes is not common³⁸. This is most likely contributed to 1) the design of the majority of existing PRO questionnaires being tailored to general populations for the assessment of physical function with the focus on activities of daily living rather than higher level tasks such as work or sport maneuvers and 2) the elevated physical fitness levels of most athletes prevent gross changes in physical function from being seen following injury in lower level daily tasks. However, these limitations should not impede clinicians from attempting to capture patient-reported information from patients classified as athletes.

Clinicians are afforded the flexibility to select metrics they feel appropriate for their patient population however; many measurement tools exist for assessing subjective physical function specific to the upper and lower extremities most of which have been deemed valid for use for specific diseases and populations, and determined to be reliable as a means of capturing patient self-perceived pain and dysfunction^{18,46,51,114-127}. Most instruments were designed with the intent of being inclusive for a general population, constructed of questions centered on a patient's perception of pain and/or the ability to perform activities of daily living. Few of the established instruments measure a person's ability to perform athletic tasks such as overhead throwing or running, cutting, and maneuvering. Upper extremity specific instruments such as the Disabilities of Arm Shoulder and Hand¹¹⁵ and L'Insalata Shoulder Questionnaire¹¹⁶ contain optional components for sports/work tasks but do not address sport-specific performance parameters in the main portion of either instrument. However, a recently designed

instrument specific for overhead athletic performance and function known as the Kerlan Jobe Orthopaedic Center Shoulder and Elbow Score (KJOC)⁵¹ has been shown to adequately measure physical function in overhead athletes.

The KJOC is comprised of 10 individual questions scored via visual analogue scales, 10 centimeters (cm) in length. The KJOC is scored by summing the results of the 10 questions with the total score being reported from 0-100 (with 100 indicating high level of function or “best” score). The reported test-retest reliability for the KJOC has been an ICC of 0.88 while the measurement error has been found to be 3 points for individuals with previous shoulder injury and 4 points for those with previous elbow injury⁵¹. It has been shown to not only be valid and reliable but also more accurate at determining dysfunction in throwing performance¹²⁸. Specifically, Neri et al found the KJOC was more sensitive to change over time in baseball athletes following shoulder surgery (average score=77) compared to the American Shoulder and Elbow Surgeons score (average score=94), an instrument commonly used in orthopedic surgery and primarily assesses shoulder function during activities of daily living¹²⁸. A research team who examined asymptomatic professional baseball pitchers currently participating in unlimited baseball activities found high group KJOC scores (≥ 90) but relatively lower individual scores leading the authors to suggest using person-specific scores rather than group scores when interpreting individual self-reported function¹²⁹. Although the KJOC is the most athlete-specific upper extremity PRO questionnaire, most of the published literature regarding the KJOC is focused on baseball players. There is only 1 non-baseball study which utilized the KJOC. Wymore and Fronek recently examined collegiate swimmers with and without current injury finding that swimmers without injured had an

average score of 84 while swimmers with injury had a significantly lower score of 54¹³⁰. Although there are relatively few articles specific to the KJOC, the negative influence of injury on the KJOC score is evident in overhead athletes. Continued research should focus on the value of the KJOC in a general population of athletes representing multiple sports and activities.

Conversely, there is more robust literature which has documented the use of lower extremity specific PROs in rehabilitation applicable to both athletic and non-athletic populations^{16,46-50,122,131-135}. Of particular interest is the Knee Injury and Osteoarthritis Outcomes Score (KOOS)⁴⁶ and the Foot and Ankle Disability Index (FADI)¹³⁵. The KOOS was designed to assess lower extremity function in non-athletic and athletic persons with knee pain and knee injury^{46,49,50}. The KOOS contains 5 sub-sections asking a participant to rate his or her relative status regarding pain, symptoms, activities of daily living, sports and recreation, and knee-related quality of life⁴⁶. Each of the 5 sub-sections are comprised of a series of 5 point Likert scales which are then transformed to be read from 0-100 (with 100 indicating high level of function or “best” score) and are scored separately. Each of the 5 sub-sections have been reported to have excellent test-retest reliability with intraclass correlation coefficients (ICC) noted as: pain=0.85, symptoms=0.93, activities of daily living=0.75, sport and recreation function=0.81, and knee-related quality of life=0.86⁴⁶. The 2 sections most specific to athletes, sports and recreation function and knee-related quality of life, have been found to be superior to subjective components of other PROs in assessing athletic function⁴⁹. The effectiveness of the KOOS however has mostly been determined in ACL deficient and/or reconstructed patients which creates a clinical and knowledge gap regarding the use of the instrument

for other knee conditions^{134,136-139}. However, Ingelsrud et al reported patient-derived KOOS values at 6, 12, and 24 months following surgery obtained from approximately 600 Norwegian patients who underwent ACL reconstruction¹³⁶. The patients were self-categorized into 1 of 3 groups: patients who felt their symptoms were acceptable following surgery, patients who were undecided about the success of the surgery, and patients who felt surgery failed. The KOOS scores for each group and time points have been reproduced in Table 2.1.

The FADI, which was designed to assess patient-perceived functional limitations of foot and ankle conditions, is comprised of 2 subscales, pain/ activities of daily living and sport activities¹³⁵. The FADI includes 26 items (4 pain-specific items and 22 task-specific items) while the FADI Sport includes 8 items. Each item is scored from 0 (unbearable pain or unable to do) to 4 (no pain or no difficulty at all) with higher scores equating to higher levels of ankle function. The FADI has a total possible score of 104 points, while the total of the FADI-Sport is 32 points. The FADI and FADI Sport are scored separately as percentages, with 100% indicating no dysfunction⁴⁸. This ankle specific measure has been found to have excellent test/re-test reliability and can discriminate between individuals with and without chronic ankle instability⁴⁸. Wikstrom et al¹⁴⁰ conducted a study comparing FADI and FADI Sport scores between subjects classified as “copers” (individuals who sustained a previous ankle sprain but have not had any residual symptoms of instability) and subjects with chronic ankle instability (patients who have continual consequences of ankle instability). There was little difference in subjective reports of ankle function between the 2 groups, with the copers reporting FADI and FADI Sport scores of approximately 98% on both scales and those with

chronic instability reporting scores of 95% on the FADI and 93% on the FADI Sport¹⁴⁰. Conversely, McKeon et al¹⁴¹ examined the effectiveness of balance training on subjects with self-reported chronic ankle instability and found that subjects enrolled in the study had lower FADI and FADI Sport scores (FADI \geq 83% and FADI Sport \geq 66%) compared to that of Wikstrom et al. Currently, a standard threshold of classifying an individual as having ankle instability per the FADI does not exist.

Of particular interest is the paucity of information regarding the effect of history of injury on the results of KJOC, KOOS, and FADI in able-bodied athletes. Further investigations into the clinical utility of the KJOC confirmed that an average score of 91 is routine for baseball pitchers however; a history of upper extremity injury significantly reduced the average score to 87 while a history of upper extremity surgery reduced the average score to 75⁵². A recent report utilized the KOOS instrument in order to examine the difference in activity of daily living and athletic function between military cadets with and without a history of knee ligament injury upon entrance into a formal military institution⁵⁰. It was reported that those with a history of knee ligament injury had significantly lower KOOS scores (2-11 points lower) although all persons medically passed the entrance physical examination to attend a military-based institution. The findings in these limited reports suggest that previous injury can negatively affect self-perceived physical function even though athletes may be able to physically execute dynamic tasks. In regards to ankle function, differences in FADI and FADI Sport scores were noted in different types and level of athletes. A significant difference in FADI (89% vs. 99%) and FADI Sport (24% vs. 30%) scores was noted to exist between elite and non-elite athletes, respectively, who did not have chronic ankle instability¹⁴². The athletes

were not assessed for a history of previous ankle injury however the elite athletes reported a current pain level of 3 out of 10 whereas the non-elite reported a pain level of 1 out of 10 which was statistically different.

Subjective assessments of physical function are critical to perform in order to place complaints or concerns in context to an individual patient. However, clinicians also administer physical tests and measurements in order to objectively assess physiological and demonstrable physical function as a means of complementing the results derived from the subjective portion of an examination. This comprehensive evaluation approach has been theorized to be more advantageous compared to single component assessments because a more complete diagnosis can be made thus improving the development of appropriate rehabilitation regimens¹³. Therefore, a review of existing physical measurements and their application in clinical practice is warranted.

Selecting Appropriate Physical Performance Measures

As important as impairment testing and PRO completion is for assessing progress in the secure rehabilitation setting, it has been recognized that the single component measurements do not necessarily translate to a patient's ability to perform a highly skilled dynamic task^{16,51}. For example, a baseball player's ability to elevate his arm to 150° in the sagittal plane or his self-reported opinion about how well his arm feels on a particular day, does not give any indication that he could effectively throw a ball overhead. In this clinical scenario, it would be imperative for a clinician to assess the player's ability to perform the task(s) necessary to participate in the sport of interest beyond standard single planar measurements and the athlete's individual opinion to justify allowing the athlete to return to sport participation. A similar rationale has been described for the lower

extremity which lead to the development of functional testing for the lower portion of the body¹⁶.

Functional testing is a mechanism which incorporates task or sports specific maneuvers into an isolated environment allowing the clinician to quantitatively and/or qualitatively assess a person's performance of a specific task. Functional trials are assessments of skills designed to tax the local and global tissues involved in the initial injury. The trials provide the clinician with an observable depiction of integrated function and/or a quantifiable result (time, strength, endurance, etc.) allowing judgments to be made regarding the safe return to the sport of interest based on the performance of the task(s)¹⁶. However, a recent report suggested the label "physical performance measure" (PPM) is a more proper descriptor of such testing maneuvers because most maneuvers only assess one aspect of function (the physical aspect) therefore broadly labeling a test simply as a measure of "function" may not be accurate⁵.

Testing for the upper and lower extremity has been directed at identifying deficiencies during such maneuvers as the assessment of dynamic strength as well as unilateral and bilateral performance of the limb as a single unit¹⁶. Clinical decisions regarding injury risk or return to activity are qualitatively and/or quantitatively based on an athlete's ability or inability to perform any of these maneuvers. In theory, assessment of sport-specific physical function, both before injury and following treatment, will provide information beyond traditional clinical measures which will help identify if the patient has actually returned to a level of pre-injured physical function as compared to utilizing the traditional information alone.

Lower extremity PPMs have been used to identify athletes at risk for a sports-related injury and for determining readiness to return to activity following injury^{22,25,143-149}. The existing lower extremity PPMs have various designs including single planar tasks (single leg step down and single leg hop for distance)^{22,25-27,149-151}, multi-planar tasks (the Star Excursion Balance Test (SEBT))^{144,146}, and agility tasks requiring running and maneuvering in various planes of motion (agility t-test and lower extremity functional test (LEFT))^{25,152-155}. The single-leg hop for distance (SLHD) has been utilized by many clinicians to assess lower extremity physical function in athletes following knee injury and/or knee surgery^{23,99,156-158} while the SEBT has been used primarily to predict lower extremity injury occurrence^{144,146,147}. Normative values for both males and females have been reported for both the SLHD and SEBT^{66,144}. Due to differences in performance between and within sexes, it may be more accurate to normalize each test result to the individual performing the task with an appropriate anthropometric value. For example, the distance hopped on the SLHD could be influenced by the mass of the person. English et al advocated calculating hop work (body weight x distance hopped) in order to normalize the test result to body weight to help control for differences between persons and provide clinicians with more accurate information regarding a single person's physical function¹⁵¹. Similarly, normalizing the SEBT to the leg length of the person performing the test is recommended¹⁴⁴.

Of concern is that the SLHD has reported excellent test/re-test and/or interrater reliability yet a recent systematic review which assessed the methodological quality of the reports determined that all studies were of poor quality¹⁵⁹. Additionally, the same review determined that the SLHD may be able to discriminate between a normal and not

normal knee but only between time of injury and up to 2 years after surgery as evidence exists that the SLHD cannot discriminate between the operative and non-operative knee or between competitive and non-competitive athletes beyond the 2 year post-surgical time frame^{159,160}. In contrast, the SEBT has been noted to have strong evidence supporting its ability to predict lower extremity injury and moderate evidence in detecting differences between stable and unstable ankles¹⁶¹. In regards to ankle injury, the SLHD does not have the ability to predict injury but can detect differences between subjects with and without ankle instability¹⁶¹⁻¹⁶³. The information for the summation was derived from various studies most of which were identified as having inadequate sample size. This weakness in the literature lead the authors of the systematic reviews to recommend that 1) adequately powered studies be conducted in order to provide sound psychometric properties for lower extremity PPMs and 2) to examine lower extremity PPMs as clinical outcome measures i.e. metrics for pre-injury screening and return to activity^{159,161}.

Unlike the lower extremity which has shown injury prediction and performance value with certain maneuvers, the upper extremity does not have a popular or single “best” test to apply for examining upper extremity physical function. The complexity of the shoulder in both anatomical design and function may contribute to the difficulty in selecting a performance task. Most clinicians err on the side of strength testing as strength is a basic physiological aspect of function i.e. strength is foundational as adequate strength permits fundamental tasks to be executed (arm elevation, stabilization, and gripping) and strength can be easily assessed in the clinical setting. While an exact test cannot be universally advocated for assessing upper extremity function, any test employed should have the capacity to help clinicians discern an individual’s ability to

utilize the arm from different physiological perspectives. Overhead throwing tasks, which are complex by design may allow clinicians to assess arm function from different perspectives but may be too specific to overhead athletes thus discriminating against non-overhead athletes recovering from shoulder injury. Therefore, PPMs which could be applicable across a gamut of athletes would likely have more clinical usefulness.

Some generalized upper extremity PPMs have been described in the literature but most have only been investigated amongst non-injured subjects^{17,20,21,164,165}. For example, Negrete et al²⁰ determined normative values for various upper extremity PPMs (modified pull-up, timed push-up, and seated shot put) and that the PPMs had excellent test/re-test reliability ($ICC \geq 0.96$). These tests were also found to be significantly correlated with the distance a softball was able to be thrown²¹. However, these maneuvers are rooted in the assessment of strength and/or power which may not provide a complete clinical picture about a person's ability to perform dynamic athletic tasks.

Examples of tests that have attempted to examine aspects of physiological function beyond strength and power (stability, agility, and endurance) and are applicable to a variety of individuals would be the upper quarter Y-balance test and the closed kinetic chain upper extremity stability test (CKCUEST)^{19,166}. The Y-balance test is performed in a pushup position with the feet no more than twelve inches apart. The subject stabilizes his or her body with one hand while performing maximal effort reaches with the free hand in three directions (medial, superolateral, and inferolateral). The distance reached in each direction is recorded. The CKCUEST is performed in a weight-bearing position requiring the individual to alternately lift and horizontally adduct one hand, touching the opposite hand in a repetitive sequence while maintaining a weight-

bearing position similar to the extended position of a push-up. Normative values have been reported a variety of athletes and between males and females for both tests (Y-balance=84-88% of limb length for males and 83-85% of limb length for females; CKCUEST=19-30 touches for males and 16-20 touches for females)^{19,166-168}. Additionally, Westrick et al determined that the Y-balance test is correlated with performance on the CKCUEST but noted that the 2 PPMs measure different aspects of upper extremity physical function¹⁶⁴.

While parameters of the Y-balance test have only been investigated in asymptomatic subjects, the CKCUEST has been found to be reliable in asymptomatic subjects as well as in subjects with subacromial impingement syndrome with test/re-test reliability being reported as excellent^{19,28}. Although the test/re-test reliability has been determined to be excellent, Tucci et al found a distinct difference in the number of CKCUEST touches performed between subjects with (10-12 touches) and without (23-28 touches) subacromial impingement syndrome²⁸. However, the subacromial impingement syndrome subjects were 24 years older on average compared to the healthy group which would suggest age may be a confounding factor. Pontillo et al have identified an association between decreased performance during physical measures of function (which included the CKCUEST), assessed prior to a competitive season, and the occurrence of injury during the season¹⁶⁹. It was found that the athletes who sustained an injury had a significantly lower number of touches during the CKCUEST compared to the athletes who did not sustain an injury. The findings of the study provide evidence that there may be a testing maneuver which can identify a reduction in physiological function which places individuals at risk for future injury. While this information regarding the

CKCUEST may be promising, it is unknown however if the CKCUEST could be reliably implemented for persons with shoulder pain younger than 50 years of age or if the test can discriminate between persons with and without shoulder pain.

Taken individually, the PROs or PPMs provide useful but limited information regarding physical function. The glaring concern is the obtainment of information related to physical function in a non-prospective or non-longitudinal manner. The PROs are typically administered to patients after injury has occurred. Traditionally, clinical and self-reported measures of physical function are obtained at initial evaluation following injury and periodically throughout treatment to determine if progress is occurring. Ultimately, a final set of measurements helps determine if an appropriate amount of change occurred from initial evaluation to the cessation of rehabilitation in order for the clinician to make the decision to discharge the patient from care. Conversely, PPMs are often utilized at the end of treatment to determine readiness to return to activity. Clinicians have begun using PPMs in a cross sectional approach as pre-injurious screening tools to predict the occurrence of injury^{147,148,169} but they have not been utilized longitudinally as a means of establishing normative baseline to be referred to later following the conclusion of treatment. Considering the common goal for rehabilitation clinicians (certified athletic trainers, occupational therapists, and physical therapists) is to not only return a patient to activity, but to return a patient to activity levels which were similar, if not identical, to the levels which occurred prior to injury, it would be prudent to have “pre-injured” baseline information specific to an individual athlete in order to truly determine if the athlete has indeed returned to pre-injured levels of activity.

The Optimal Outcome Model

It has been suggested that a modification of the traditional method for measuring physical function be expanded beyond single component measures and should instead include a comprehensive approach where traditional clinical measures, PROs, and PPMs are collectively captured⁵. Moving to a comprehensive framework would potentially allow for a more thorough assessment of physical function by accounting for multiple components or dimensions that affect task execution^{5,58}. A theoretical model, known as the Optimal Outcome Model, has been recently described which expands on the concepts established through the ICF model and comprehensive assessment of physical function framework⁶⁰. The model aims to assist practicing clinicians with assessing multiple components of physical function in order to establish an individualized treatment plan for each specific patient. The 3 main components that have been theorized to be critical to physical function include the patient, the clinician, and external factors (external factors can include but are not limited to family members, coaches, employers, transportation, and income level)⁶⁰. The 3 components are interlinked and bound by the injury or impairment requiring resolution. While previous illustrations such as the ICF model have focused on the consequences of a condition or disease, the Optimal Outcome Model describes the resultant outcome following intervention on the disease.

The Optimal Outcome Model⁶⁰ allows clinicians to address areas of needed improvement while attempting to achieve balance amongst the rehabilitation related factors. A safe zone was designed to accommodate the flexibility needed in clinical rehabilitation as some patients require greater attention in one particular area over another. It is hypothesized that as long as the outcome remains within the borders of the

model (the safe zone), then the outcome should be satisfactory (Figure 2.1). Similar to the ICF, the Optimal Outcome Model helps to illustrate that it is the responsibility of the clinician to begin the rehabilitation process by putting the condition in context to the individual patient making an attempt at creating balance amongst the physical function components to achieve the best possible outcome.

The Optimal Outcome Model helps to reduce straining one or more of the rehabilitation components which is typically caused when individual components are addressed in isolation. For example, focusing on identifying and treating only impairments found on the physical examination would enhance the clinician component but could strain the patient-specific and external factor components as patients may only be concerned with return to activity rather than the obtainment of a specific amount of strength or range of motion¹⁰⁸. It is becoming more recognized that in addition to physical impairments, factors surrounding the patient and the patient's external environment can also influence the outcome thus compounding treatment plans. Not all patients require equal amounts of attention on all 3 components of physical function in the rehabilitation process thus each patient will have specific need and/or goal that is unique to that individual. This is why clinicians establish patient-specific goals prior to the initiation of treatment. However, as previously noted, pre-injured assessment of physical function currently does not occur.

Measuring patient physical function prior to the beginning of *treatment* currently occurs routinely in physician and physical therapy practices although this practice may not be completely accurate when trying to determine if return to pre-injured activity levels has occurred. In order to help limit possible strains on one or more of the

components in the Optimal Outcome Model, information regarding an individual patient's ability to perform dynamic tasks prior to *injury* would strength a clinician's ability to discern if return to pre-injured levels of activity did indeed take place. Unfortunately, knowledge of pre-injured physical function can be difficult to obtain in the traditional rehabilitation setting (i.e. physical or occupational therapy settings) as the initial interaction between the patient and clinician ensues following the occurrence of injury rather than before injury occurrence. Conversely, the athletic training profession may be better equipped to assess pre-injured physical function as certified athletic trainers routinely assist physicians in the execution of pre-participation athletic physical examinations. However, these examinations are performed to determine medical qualification for athletic participation rather than as a prospective patient-specific data capture^{30,31}. Collecting pre-injured information from athletes specific to physical function would be in line with the tenets of the Optimal Outcome Model where obtaining person-specific information prior to injury would benefit rehabilitation clinicians by providing true pre-injured information to utilize throughout the rehabilitation process, from initial goal setting through return to play decision making.

The Need for Longitudinal Assessment of Physical Function

Physical function is clinically assessed at different time points and for specific reasons. Screening athletes prior to the beginning of an athletic season currently occurs for the purpose of medical qualification to participate in physical activities. A pre-participation physical examination (PPE) is a comprehensive screening mechanism constructed of a battery of tests including but not limited to examinations of previous injury history, vision, vital signs, and musculoskeletal integrity³⁰. A key aspect of the

PPE is that it serves as a screening tool to identify underlying deficits which could lead to injury rather than establish a diagnosis. In other words, an athlete does not usually attend a PPE seeking a diagnosis for an existing condition thus the expectation of receiving a diagnosis of tissue derangement or other identified anatomical lesion is minimal³¹. Conversely, following the occurrence of injury, clinicians will disseminate the findings from the application of similar examination techniques utilized in a PPE to provide a specific diagnosis as part of the initial injury examination. This so called impairment testing has been shown to be helpful in identifying physical deficiencies at the beginning of rehabilitation and in determining improvement or success in non-operative and post-operative clinical scenarios throughout and following rehabilitation^{14,32-35}. On the other end of the continuum, (at the conclusion of rehabilitation following injury), is when the PPMs are typically employed for the purpose of determining readiness to return to activity^{3,36}.

Demonstrable physical performance is only one of many factors of physical function that must be considered when making a return to play decision^{3,36}. Matheson et al noted that a systematic review of the return to play literature revealed 74% of articles routinely advocate addressing medical factors such as physical exam results, imaging, and functional tests as items of importance in the return to play process, yet only 26% considered other factors such as participation risk (type of sport, position, competitive level, etc.) or decision modifiers (timing and season, pressure from athlete, pressure from coach, masking injury, etc.)³⁶. This does not suggest that medical factors do not have importance when determining readiness to return to activity, but it highlights that return to play decision making is a complex process and much like the theme of the ICF and

Optimal Outcome Model, return to play should be individualized to each patient.

As noted, return to pre-injured levels of play is a common goal for clinicians and patients. A number of outcomes studies have suggested that return to athletic participation is possible following injury and/or surgery^{128,170-180}. However, full return to pre-injury level of activity has been shown to be elusive for some individuals. The orthopedic literature has reported an inconsistent rate of return to pre-injured level of activity for overhead athletes following selected shoulder surgeries (8-94%) with non-overhead athletes having at least 2x greater chances to return to full levels of activity²⁹. Similar findings have been reported for non-overhead athletes following selected knee surgeries (56-89%)^{98,99,181}.

The explanation for the variation in return to play rate is based on multiple factors including differences in distinct surgical approaches, failure to report or document the size or type of primary lesions, presence of concomitant injury, surgical technique (open or arthroscopic), or type and amount of hardware used. In some instances, return to activity was not operationally defined so it is not known if return to play meant return to full function or return with limitation^{171,174}. Ardern et al found that 90% of patients recovering from ACL reconstruction achieved successful outcomes based on resolution of physical impairments yet only 63% of athletes returned to pre-injured levels of activity. They suggested that psychological factors such as fear of re-injury may be influencing the low return to play rate which implies a clinical measure or PPM as an isolated measure only provides a portion of the information needed for determining readiness to return to activity.

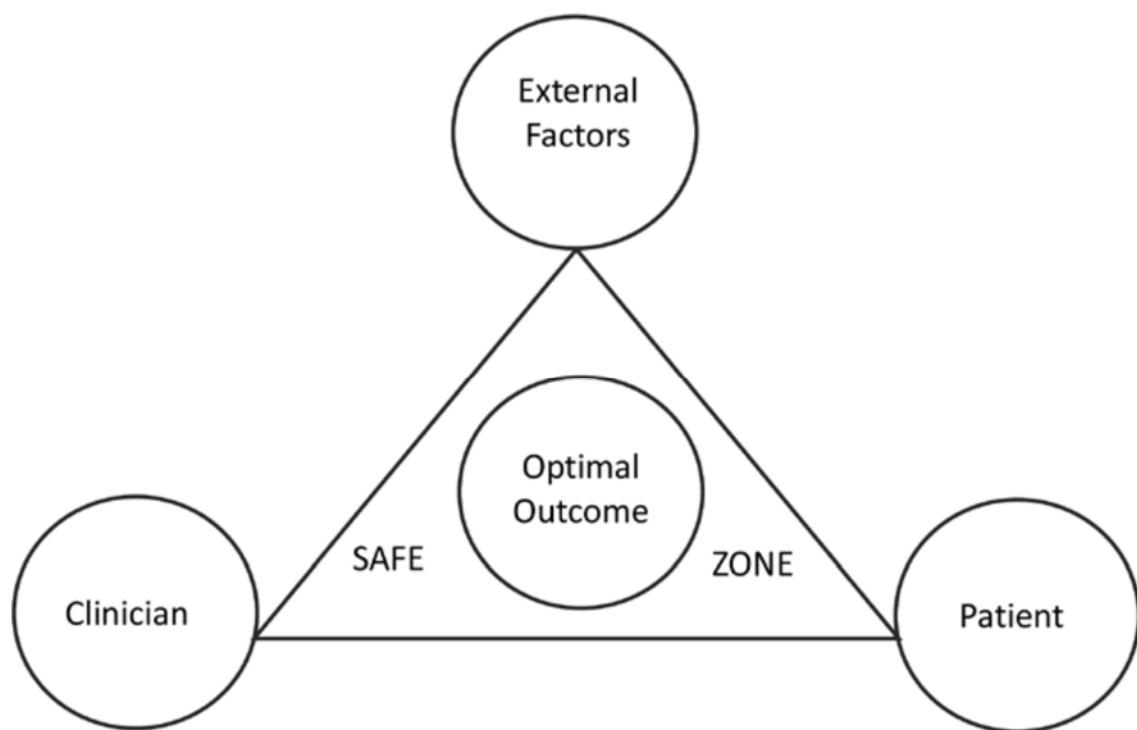
The consistent gap however amongst studies reporting a return to pre-injured

level of activity was that the studies were of a retrospective design and each article lacked a measurable means of clinically determining physical function prior to release to activity, or more importantly, prior to the injurious event²⁹. Without a pre-injured baseline measure or a post-treatment measure of athletic performance, it is unknown if the athletes were released from rehabilitation prematurely. If return to activity occurred after impairment restoration but before functional restoration was achieved, then it may be a possible explanation as to why the return to pre-injured level is so variable. It is unknown if those athletes who failed to return to pre-injured levels was entirely dependent on clinical interventions. Post-surgical success may have occurred as far as restoring compromised anatomy (i.e. repairing or reconstructing torn tissue) and athletes may have achieved the capability to perform sporting activities however the athlete may have made the personal decision to no longer continue with the activity. The subjective nature of the data collection in previous work is inherently biased with multiple unknown factors. A possible suggestion for overcoming these methodological limitations would be to employ a comprehensive, multi-faceted assessment approach through the rehabilitation process beginning with the PPE. The effectiveness of this approach would be enhanced by obtaining information prior to injury to serve as baseline comparators in the event injury occurs in the future. This would be similar to head injury assessment models which attempt to establish physical and cognitive function prior to the occurrence of a head injury^{61,62}. The baseline information could be referred to at the return to play time period to determine if an athlete has returned to perceived and demonstrable physical function which in turn would assist in making more accurate determinations of return to pre-injured levels of activity.

Table 2.1. Post-operative KOOS Values from Ingelsrud et al Am J Sports Med 2015 (n=598)

	Pain	Symptoms	Activities of Daily Living	Sports/ Recreation	Quality of Life
Acceptable					
Symptoms					
6 months	88	83	94	69	72
12 months	88	82	95	70	72
24 months	91	85	96	77	76
Undecided					
6 months	79	73	89	51	51
12 months	77	71	88	51	49
24 months	68	65	78	39	42
Failed Surgery					
6 months	58	55	69	26	27
12 months	57	55	69	25	24
24 months	58	57	73	33	31

Figure 2.1. The Optimal Outcome Model



Chapter Three: Pre-Season Perceived Physical Capability is affected by Previous Injury

Introduction

Patient perception regarding his or her ability to perform physical maneuvers, either during activities of daily living (ADLs) or more challenging tasks such as those specific to athletic performance, has become an important piece of the medical assessment process. In addition to routine clinical measures of motion and strength, accounting for perceived physical capability (the patient's opinion about his or her ability to perform athletic maneuvers at a specific point in time) has been theorized to contribute to the overall success of patient outcomes in rehabilitation because it integrates the subjective information with objective measures specific to an individual patient^{56,57,59,60,182}. It is reasonable to assume that in addition to demonstrable clinical or performance maneuvers, an athlete's perceived physical capability to perform athletic tasks is an important consideration for returning to active competition. When an injury occurs, the common goal for both athlete and clinician is to return the athlete to activity to at least the pre-injured level of capability. Ideally, returning the athlete to "pre-injured" levels of objective physical capabilities (demonstrable tasks) while accounting for subjective considerations (perceived tasks) where, the athlete perceives his/her level of physical capability and quality of life as restored relative to the injured structure, would assist clinicians in obtaining optimal outcomes through the use of integrated information.

Patient-oriented outcome measures have become a common component of injury assessment in sports medicine and orthopedics. Collection of self-reported patient outcomes typically occurs by administering a reliable questionnaire following an injury. The questionnaires routinely ask a patient to rate his or her self-perceived ability to

perform activities of daily living and/or more challenging tasks such as sports or recreational activities (running, pivoting, throwing, etc.). Traditionally, these measures are obtained at initial injury evaluation and periodically throughout treatment or at least at discharge to determine if progress is occurring. Ultimately, a final set of measurements helps determine if an appropriate amount of change occurred from initial evaluation to the cessation of rehabilitation in order for the clinician to make the decision to discharge the patient from care. However, considering that the clinical goal is to return the patient to pre-injured levels of performance, it is currently unknown as to how the individual athlete perceived him or herself prior to the injury occurring. This gap has been evident in previous case series which have reported return to play rates and/or return to pre-injured levels of athletic performance based on asking patients 2 years or more after discharge if he or she had returned to pre-injured levels of activity^{156,170-173,183}. The lack of a prospective assessment of pre-injured baseline capability either in a subjective or objective manner, decreases the ability to confirm if the athletes had returned to pre-injured levels of activity. The retrospective assessments performed in the case series reports are unfortunately limited in interpretation due to the possibility of recall bias by the patients because of the length of time between injury, cessation of treatment, and clinical follow-up.

A recent cross-sectional study obtained prospective outcomes scores for incoming military cadets with and without a history of knee ligament injury⁵⁰. The researchers found that individuals with a history of knee ligament injury had lower scores (0-12 point difference in median value) versus those who did not have an injury history per the Knee Injury and Osteoarthritis Outcome Score⁵⁰. This study has helped to identify a

potential relationship between the occurrence of a previous injury and current lower perceived physical capability after supposed injury resolution. However, because the previous work focused on 1 anatomical joint and 1 distinct population it would be beneficial to know if a history of injury specific to different anatomical joints has a similar impact on the perceived physical capability of a heterogeneous population. Therefore, the primary outcome for this study was to perform a descriptive analysis for knee, shoulder, and elbow perceived measures of physical capability during pre-participation physical examinations for various collegiate athletes. Self-perceived physical capability was assessed by distributing selected subscales of the Knee Injury and Osteoarthritis Outcome Score outcomes questionnaire and the Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Score. The secondary purpose of this study was to investigate potential differences in outcome scores between individuals with and without a history of injury. The hypothesis was that athletes with a history of injury would have lower outcomes scores indicating decreased perceived physical capability when performing sport activities.

Materials and Methods

Design and Setting

In order to answer the primary question, a cross-sectional study to assess pre-season self-perceived physical capability specific to athletics was conducted. The authors employed the cross-sectional design to evaluate differences in knee, shoulder, and elbow scores between athletes with and without a self-reported upper or lower extremity injury history during pre-season physical examinations. The knee, shoulder, and elbow, were selected as anatomical joints of interest because over 75% of the injuries seen in the

primary author's facility occur at or around these joints.

Participants

Athletes were recruited from 5 institutions (3 National Association of Intercollegiate Athletic institutions, 1 National Collegiate Athletic Association (NCAA) Division III institution, and 1 NCAA Division I institution) currently receiving physician and/or athletic training services by the primary or senior author's facilities. Each participant was approached to complete a hard copy survey packet during pre-season pre-participation physical examinations and were included if the athlete was medically cleared to participate in sport per the team physician. Participants were excluded if they were being actively treated for a musculoskeletal injury not allowing them to participate in athletics or the physical examination did not result in the athlete being medically cleared to participate in sport. The research team was invited to attend select physical examination dates provided by each school's athletic training and medical staff. The invitation was extended to the research team to attend specific dates through the middle to late summer prior to the beginning of the fall sports season where the largest number of physical examinations would be conducted. Subject recruitment and survey completion only occurred through the research team at the attended physical examinations. Participants were briefed on the purpose of the surveys, any potential risks, and were given the decision to be excluded from the study. Participants were also informed that no identifiable protected health information (PHI) would be collected. The study was reviewed and approved by an institutional review board with the study being granted a waiver for informed consent due to the lack of identifiable PHI collection.

Study Questionnaires

Following the performance of the physical examination by a team physician and receiving medical clearance to participate in sport, each participant was asked to complete a general information demographic form which included age, years participating in the present sport, sex, history of injury, and sport. History of injury was presented in a binary fashion (yes or no) for 3 anatomical joints of interest: knee, shoulder, and elbow e.g. “Have you ever had a shoulder injury”. History of injury was not specifically defined as it has been in previous work where the loss of at least 1 day of athletic participation occurred or an event requiring medical attention took place⁹⁴. This was done intentionally in order to not hinder individual perception, allowing for personal experiences to influence the survey responses. Using patient experiences as defined by the individual was felt to reflect daily clinician/patient interaction during a clinical assessment. Therefore, the definition of injury was defined as “any event an individual could recall that he or she would personally consider to be an episode of injury but not necessarily sustained during participation in athletics”, which was fitting for the purpose of the study⁷².

In addition to the demographic information, participants were asked to complete 2 separate self-reported outcomes questionnaires, the Knee Injury and Osteoarthritis Outcome Score (KOOS)⁴⁶ and the Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Score (KJOC)⁵¹. These questionnaires were selected in an attempt to utilize instruments that could be applied across multiple sports with the understanding that no single questionnaire would be ideal for all existing sports. They were also selected due to their applicability to the knee (KOOS) and shoulder/elbow (KJOC) as well as for their

usefulness for gauging athletic-specific maneuvers in athletic populations rather than the performance of less rigorous activities of daily living. Self-perceived physical capability was defined as the individual athlete's view regarding his or her ability to perform athletic tasks based on the current personal view of each specific joint. Neither the instructions nor questions of the KOOS subscales or the KJOC were modified from their original construct.

The KOOS contains 5 sub-sections asking a participant to rate his or her relative status regarding symptoms, pain, activities of daily living, sports and recreation, and knee-related quality of life⁴⁶. Each of the 5 sub-sections are comprised of a series of 5 point Likert scales which are then transformed to be read from 0-100 (with 100 indicating high level of physical capability or "best" score) and are scored separately. For the purposes of this study, only the Sports and Recreation Function (KOOS_{Sport}) and Knee-Related Quality of Life (KOOS_{QOL}) sections were selected due to their relevance to athletic populations and because each section of the KOOS can be scored and interpreted separately. The KOOS_{QOL} was utilized because it was hypothesized that existing knee conditions could psychologically affect knee specific activities thus, a means of capturing this phenomenon was selected. The reliability of the KOOS_{Sport} has been reported as being excellent with an intraclass coefficient of .81 with a measurement error of 8.3 points, while the KOOS_{QOL} has been reported as having an intraclass coefficient of .86 and 5.6 point measurement error⁴⁶.

The KJOC is comprised of 10 individual questions scored via visual analogue scales, 10 centimeters (cm) in length. The KJOC is scored by summing the results of the 10 questions with the total score being reported from 0-100 (with 100 indicating high

level of physical capability or “best” score). Although this questionnaire has been found to be sensitive to overhead athletes⁵¹, it was selected because of its specific questions regarding upper extremity athletic performance and to date is the most specific upper extremity athletic performance instrument available. The reported reliability for the KJOC has been an intraclass correlation of .88 while the measurement error has been found to be 3 points for previous shoulder injury and 4 points for previous elbow injury⁵¹.

Data Reduction

All paper questionnaires were manually entered into an electronic database by the research team. Using previously established scoring transformation methods⁴⁶, the KOOS items were transformed from the Likert scale categories to integers of 0-4 which allowed for the total score to be calculated on a 0-100 scale for each section. The KJOC visual analogue scales were manually measured with a standard tape measure to the nearest tenth of a centimeter. The total score for all ten questions was combined for a score on a scale of 0-100.

Statistical Analysis

Summary statistics for demographic items were calculated and reported as means and standard deviations for continuous variables while frequencies and percentages were reported for categorical variables. The primary purpose of determining the summary values for knee, shoulder, and elbow self-reported physical capability was completed by calculating summary statistics for all athletes including mean score, standard deviations, 95% confidence intervals, median score, interquartile range, minimum/maximum scores, and ceiling effects. For the secondary purpose, four specific planned comparisons were made examining the self-reported scores between individuals with and without a history

of injury for each anatomical joint and the appropriate outcomes instrument (KOOS_{Sport}: knee, KOOS_{QOL}: knee, KJOC: shoulder and elbow). Examination of normality was performed with a Shapiro-Wilk test which identified that the study variables were not normally distributed ($p < .001$). Therefore, four independent non-parametric Mann-Whitney U analyses were performed to identify the differences between injury history and each self-perceived score (KOOS_{Sport}/knee injury history; KOOS_{QOL}/knee injury history; KJOC score/shoulder injury history; and KJOC score/elbow injury history). In order to differentiate between subjects with and without a history of shoulder or elbow injury on the KJOC, each condition needed to exist separately thus when comparing subjects with and without a history of shoulder injury, subjects who also reported a history of elbow injury were excluded from the analysis. Similarly, when comparing subjects with and without a previous history of elbow injury, subjects were excluded who also reported a history of shoulder injury. Additionally, pairwise Cohen's d calculations were performed to determine the relative effect size of any differences in outcomes scores¹⁸⁴. The effect size is often used to determine if mean differences are large enough in magnitude to be considered clinically meaningful, and Cohen defined effect sizes as small, $d = 0.2$, medium, $d = 0.5$, and large, $d = 0.8$ ^{184,185}. Subjects with missing data were not included in the analyses. All statistical calculations were performed using STATA/IC (version 13.1 for Windows, StataCorp, LP, College Station, TX).

Results

Demographic information was obtained from 738 athletes from 5 collegiate institutions (Table 3.1). Athletes from 19 sports participated in the study with the greatest number of athletes actively participating in football which represented 29% of

the athletes surveyed (Table 3.2). Of the 350 athletes who reported a history of injury, a total of 445 injuries were noted where 208 reported a previous knee injury, 180 reported having a previous shoulder injury, and 57 reported a previous elbow injury. The median values for the KOOS_{Sport}, KOOS_{QOL}, and KJOC for all 738 athletes were 100 (Table 3.3). The athletes with previous joint injuries reported significantly lower perceived physical capability ($p < .001$) on both KOOS subscales and the KJOC (Table 3.4). The effect sizes for the differences were large ranging from .89-1.4 for the KOOS subscale scores and 1.2 – 1.3 for the KJOC scores.

Discussion

Self-reported outcome questionnaires are regularly used to assess a person's current perceived ability to perform activities of daily living and/or more demanding tasks such as maneuvers performed in athletics^{46,51,115,118,119}. These questionnaires are often initially distributed at the initiation of rehabilitation (i.e. at a time when a person is in an injured state) and assist clinicians in measuring changes as the person progresses through the recovery process culminating with discharge from formal treatment and the return to an individual's desired activity. Return to athletic activity following rehabilitation often carries the stigma of returning to "pre-injured" levels of play however; there are limited reports of measuring self-perceived ability to perform athletic tasks prior to the exposure to injury^{50,52,53,129}. Thus, this study was carried out to identify baseline self-reported physical capability relative to the perceived state of the knee, shoulder, and elbow in a wide array of athletes before the commencement of injury exposure.

The first main finding from the current study indicates that overall, collegiate

athletes report upper level scores on selected KOOS subscales and the KJOC similar to values previously reported in the literature^{50-52,129}. The fact that the majority of athletes in this study reported high scores, and in a majority of cases perfect scores, was not unexpected as they were asked to complete the questionnaires at a time when they were assumed to be uninhibited by injury. Additionally, the athletes were medically cleared by the team physician(s) prior to completing the questionnaires adding another level of expectation for high scoring. However, while self-perceived scores for a heterogeneous group of athletes were able to be obtained, it may be more reasonable to make clinical decisions and determinations as they relate to the individual person^{60,129}. While the current study aimed to identify group characteristics, it is reasonable to suggest that results specific to an individual person may be more appropriate for making more accurate clinical decisions about that person as group scores could mask individual concerns.

The second finding occurred following the demarcation of the athletes based on injury history. The high overall scores decreased when a previous injury was noted despite all study participants receiving medical clearance to compete in their sport. The reduction in score was more evident for participants with previous knee injury as measured by the KOOS_{QOL} and with a previous shoulder injury as measured by the KJOC. These findings suggest that previous injury can indeed negatively impact an individual's perceived physical capability. The meaningfulness of an identified relationship between history of injury and perceived physical capability is strengthened by the observed differences exceeding reported measurement errors for the outcome instruments as well as the resultant large effect sizes.

Recent investigations have shown certain active groups with a history of injury to also have lower outcomes scores and increased symptoms both prior to and following the commencement of physical activity^{50,52,53}. Active professional baseball players and military cadets with a history of injury have been shown to have lower perceived outcomes scores which were assessed via the same questionnaires utilized in this study^{50,52}. Similarly, a mid-season assessment of non-injured collegiate athletes (using other upper extremity questionnaires not distributed in the current study including the Rowe Shoulder Score, Simple Shoulder Test, American Shoulder and Elbow Surgeons Score, Constant-Murley Shoulder Score, and the UCLA End-Result Score) found an increased incidence of shoulder-related symptoms in athletes with previous injury⁵³. These findings highlight the importance of comprehensive screening of all athletes because traditional medical qualification does not necessarily account for the individual athlete's perception of his or her ability to perform dynamic athletic maneuvers, whether basic (forward running or jumping) or complex (throwing, striking, or cutting), during sport activities. With the current paradigm shift from the biomedical focus (disease-driven clinical care) to the biopsychosocial focus (patient as an active participant)¹⁰⁷, parallel screening involving both the traditional medical examination and the assessment of self-perceived physical capability would be recommended to provide a broader view of individual persons and factors which could have a negative impact on physical performance and/or well-being. Furthermore, supplementing the patient-reported outcome measures with some assessment of injury history would likely provide clinicians with another layer of information as to why a specific magnitude of outcome score resulted.

Considering that it is also established that a predictor of future injury is past injury, prospective assessment of injury history and perceived physical capability may help clinicians identify athletes at risk for future injury^{73,186,187}. This previous work has been pivotal in identifying factors that contribute to injury risk however; prospective assessment of perceived physical capability via the questionnaires utilized in the current study has not been previously utilized as a means of injury prediction. It is possible that the combination of an injury history questionnaire and a patient-reported outcome measure such as the KOOS or KJOC could serve as a means of identifying an athlete who has had a previous injury yet is able to participate in his or her respective sport but not feel as though a previously affected knee or shoulder is completely optimal based on the previous injury experiences. The prospective method of assessment could help identify the existence of potential impairments possibly present as a result of incomplete recovery or rehabilitation from past injury. Additionally, identifying individuals with previous injury and obtaining their perceived ability to physically perform could allow clinicians to be efficient in developing injury prevention programs specific to an individual where identifying scores below a certain threshold for a specific person rather than for an entire team may help in individualizing treatment plans. While it is beyond the scope of this project's findings, perhaps future research could investigate if athletes who have had previous injury perceive their physical performance capability to be lower than reported reference values and may be at a greater risk for future injury.

While recognized as a potential limitation of this study, loosely defining the term injury allowed participants to self-define injury in his or her personal context. The broad description allowed each participant to utilize his or her own perception and definition of

what an injury was. It was opined that injury could occur at any place or any time, not necessarily specific to athletics, such as when an athlete was not practicing or competing (i.e. the off-season), therefore; restricting the definition to lost participation time or only conditions where medical treatment was sought would potentially eliminate personal and/or contextual definitions of injury⁷². The self-reported values detailed in this study showed that however an individual chose to define an injury, it was important enough for the occurrence to be recalled and to produce a significant difference in the reported scores for both upper and lower extremity questionnaires. The findings from this study are most appropriately interpreted as showing a connection between reporting lower perceived physical capability relative to a pre-determined “best” score and having sustained a previous injury to the knee, shoulder, or elbow. The exact values in this report should not be used as a cut-point for making clinical decisions about the ability or inability to perform athletic tasks. Future studies should further investigate the clinical utility of the self-reported measures provided by athletes prior to the beginning of a competitive season.

There are other potential limitations in this study. First, the KJOC has 1 question related to pain but does not have a specific pain score or section while other sections of the KOOS not distributed in this study provide scores for symptoms and for pain. Due to the lack of a specific symptoms and/or pain score on the KJOC, it was decided to not distribute those same sub-sections of the KOOS in order to capture similar information between the 2 questionnaires. It was also decided to not administer all KOOS sub-sections in order to focus on specific components most relevant to athletes i.e. questions specific to perceived physical capability. The authors felt the primary study question

could be appropriately answered in the executed manner due to the understanding that each section of the KOOS can be scored and interpreted separately. Second, the binary design of the history of injury questions does not account for severity of pain/injury, type of injury, or duration of injury. It is possible that variations in perceived physical capability were related to these components however all persons were medically cleared to participate in sport and no significant examination finding was noted which would have otherwise disqualified an athlete from participation. The third limitation is that rehabilitation history or specifics of treatment were not obtained for the purposes of this study. Responses could have been affected by previous experiences with rehabilitation (if any), including number of treatments/visits, access to clinical care, and mode of treatment. It is recognized that although the participants were medically qualified to play their sport, it is possible physical deficits, impairments, and/or joint derangement could have been present and in varying severity. However, despite these noted limitations, the method of assessment for self-reported physical capability specific to athletics in this study mimics clinical practice where clinicians select questionnaires based on a litany of factors in order to include the patient component in the rehabilitation process with the understanding that not all potential confounding variables can be accounted for in clinical practice.

Conclusions

Similar to previous literature, the current study has shown that overall, perceived physical capability specific to the knee, shoulder, and elbow was high for athletes prior to the beginning of a competitive season. It is evident that athletes reporting a previous injury have perceived lower physical capability prior to a competitive season. This self-

assessment of joint specific capability may supplement pre-season physicals and indicate that particular athletes need further monitoring or care during the course of the season. While it is yet to be determined, prospective collection and use of preseason perceived physical capability may serve as a guide for goal setting in rehabilitation and return to play providing a patient-specific measure for clinicians to base clinical decisions.

Table 3.1: Descriptive Statistics for Demographic Variables

	Overall (n=738)	No Injury History (n=388)	Injury History (n=350)
Age (years)			
n	735	386	349
Mean (SD)	19 (1)	19 (1)	19 (1)
Range	17-32	17-24	17-32
Time Playing Sport (years)			
n	707	370	337
Mean (SD)	10 (4)	10 (4)	11 (4)
Range	1-20	1-19	1-20
Sex			
Male	486 (66%)	248 (64%)	238 (68%)
Female	251 (34%)	140 (36%)	111 (32%)
Year in College			
Freshman	59 (8%)	32 (9%)	27 (8%)
Sophomore	498 (69%)	278 (73%)	220 (64%)
Junior	84 (12%)	34 (9%)	50 (14%)
Senior	68 (9%)	28 (7%)	40 (12%)
5 th Year Senior or Graduate	14 (2%)	7 (2%)	7 (2%)
Knee Injury Ever			
Yes	208 (28%)		
No	529 (72%)		
Shoulder Injury Ever			
Yes	180 (24%)		
No	557 (76%)		
Elbow Injury Ever			
Yes	57 (8%)		
No	681 (92%)		

SD = standard deviation

Table 3.2: Sport Distribution for All Athletes

Sports	Count (%)
Football	213 (29%)
Sex	M (100%), F (0%)
Soccer	146 (20%)
Sex	M (61%), F (39%)
Baseball	63 (8.0%)
Sex	M (100%), F (0%)
Basketball	54 (7.0%)
Sex	M (65%), F (35%)
Volleyball	47 (6.4%)
Sex	M (0%), F (100%)
Swimming	36 (4.5%)
Sex	M (47%), F (53%)
Wrestling	31 (4.0%)
Sex	M (61%), F (39%)
Softball	27 (4.0%)
Sex	M (0%), F (100%)
Cross Country	18 (2.4%)
Sex	M (50%), F (50%)
Archery	16 (2.0%)
Sex	M (50%), F (50%)
Golf	16 (2.2%)
Sex	M (44%), F (56%)
Bowling	14 (2.0%)
Sex	M (46%), F (54%)
Lacrosse	13 (2.0%)
Sex	M (92%), F (8%)
Field Hockey	13 (2.0%)
Sex	M (0%), F (100%)
Cheerleading	11 (1.5%)
Sex	M (0%), F (100%)
Tennis	10 (1.4%)
Sex	M (60%), F (40%)
Track	6 (1.0%)
Sex	M (33%), F (67%)
Equestrian	2 (0.3%)
Sex	M (0%), F (100%)
Dance	2 (0.3%)
Sex	M (0%), F (100%)

M=male, F=female

Table 3.3: Descriptive Analysis of Perceived Physical Capability for Entire Population

Questionnaire	N	Missing	Mean (SD)	Median	Range
KOOS _{Sport}	730	8	94 (13)	100	10-100
KOOS _{QOL}	727	11	92 (15)	100	6.25-100
KJOC	734	4	94 (11)	100	17-100

KOOS_{Sport} = Knee Injury and Osteoarthritis Outcome Score Sport and Recreation Function; KOOS_{QOL} = Knee Injury and Osteoarthritis Outcome Score Knee-Related Quality of Life; KJOC = Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Score n = number of subjects; SD = standard deviation

Table 3.4: Comparison of Perceived Physical Capability by History of Injury

Kerlan Jobe Orthopaedic Clinic Shoulder and Elbow Score									
	N	Mean (SD)	95% CI	P-value	ES	ES CI	Median	IQR	Ceiling Effect (%)
Shoulder Injury Ever	180	85 (18)	83-88	P<.001	1.2	1-1.4	93	22	22
No Shoulder Injury Ever	516	98 (5)	97-98				100	3	53
Kerlan Jobe Orthopaedic Clinic Shoulder and Elbow Score									
	N	Mean (SD)	95% CI	P-value	ES	ES CI	Median	IQR	Ceiling Effect (%)
Elbow Injury Ever	57	89 (14)	85-93	P<.001	1.3	1-1.6	97	16	25
No Elbow Injury Ever	516	98 (5)	97-98				100	3	53
Knee Injury and Osteoarthritis Outcome Score Sports and Recreation Function Subscale									
	N	Mean (SD)	95% CI	P-value	ES	ES CI	Median	IQR	Ceiling Effect (%)
Knee Injury Ever	208	86 (18)	84-89	P<.001	.89	.73-1.1	95	25	44
No Knee Injury Ever	521	97 (9)	96-98				100	0	81
Knee Injury and Osteoarthritis Outcome Score Quality of Life Subscale									
	N	Mean (SD)	95% CI	P-value	ES	ES CI	Median	IQR	Ceiling Effect (%)
Knee Injury Ever	208	80 (20)	77-82	P<.001	1.4	1.2-1.5	88	31	29
No Knee Injury Ever	518	97 (8)	96-98				100	0	83

n = number of subjects; SD = standard deviation; 95% CI = 95% confidence interval; ES = effect size; ES CI=effect size confidence interval; IQR = interquartile range

Chapter Four: Reliability of Strength and Performance Testing Measures and Their Ability to Differentiate Persons with and without Shoulder Symptoms

Introduction

Functional testing is a mechanism which incorporates task or sports specific maneuvers into the traditional rehabilitation environment allowing the clinician to qualitatively and/or quantitatively assess a person's performance of a specific task. The testing provides the clinician with an observable depiction of dynamic physical function and/or a quantifiable result (time, strength, endurance, etc.), allowing judgments to be made regarding the successful resolution of impairments and/or the safe return to the sport of interest based on the performance of the task(s)¹⁶. However, a recent report suggested the label "physical performance measure" is a more proper descriptor of such testing maneuvers because most maneuvers only assess one aspect of function (the physical aspect); therefore, broadly labeling a test as a measure "function" may not be accurate⁵.

Physical performance measures specific to the upper extremity exist but none have been universally accepted as the primary means of gauging readiness to return to activity following the completion of musculoskeletal rehabilitation. Unlike maneuvers described for the lower extremity which have reported injury prediction and performance value (in particular, the single leg hop and step-down maneuvers)²⁵⁻²⁷, the upper extremity does not have a single best test to utilize for performance assessment likely due to the variation in the demands of different sports on the upper extremity. For example, the demands of an American football lineman require both closed and open chain arm movements which differ from the demands on a quarterback who is required to perform primarily open chain movements with the overhead throwing motion. Due to the absence

of a gold standard of assessment for upper extremity physical performance, clinicians will often utilize some variation of strength testing as the post-intervention metric because strength is a basic physiological component of physical task performance permitting fundamental tasks to be executed (such is the rationale for routinely conducting manual muscle testing procedures during clinical examinations and throughout rehabilitation). Strength measures for the upper extremity are employed in the clinical setting to determine side to side differences between involved and non-involved limbs. The strength measures can be reliably implemented^{69,188-191}, possibly adding justification for their routine use. However, they have not been examined in the literature for value regarding return to activity. Furthermore, as important as strength testing is for identifying potential impairments and assessing progress in the secure rehabilitation setting, it has been recognized that single component physiological measurements of strength, mobility, endurance, or pain do not necessarily translate to a patient's ability to perform a highly skilled dynamic task^{13,16}.

Strength measures are possibly utilized as a rehabilitation progression or discharge metric because there is a lack of a gold standard for assessing upper extremity performance. Numerous physical performance measures for the upper extremity have been described in the literature. However, most maneuvers are either time consuming to implement, complex to perform, or are applicable to specific sports and do not translate across a variety of activities^{21,24}. One test which could potentially overcome the implementation obstacles and may be applicable to a variety of sports would be the closed kinetic chain upper extremity stability test (CKCUEST)¹⁹. The maneuver is performed in a weight-bearing position requiring the individual to alternately lift and

horizontally adduct one hand, touching the opposite hand in a repetitive sequence while maintaining a weight-bearing position similar to the extended position of a push-up. The CKCUEST has been found to be reliable in asymptomatic subjects and subjects with subacromial impingement syndrome with test/re-test reliability being reported as excellent^{19,28}. Additionally, a recent report identified an association between decreased pre-season performance on the CKCUEST and the occurrence of shoulder injury during the season¹⁶⁹. It was found that the athletes who sustained an in-season injury had a significantly lower number of touches at the beginning of the season during the CKCUEST compared to the athletes who did not sustain injury. The findings of the study provide evidence that there may be a testing maneuver which can identify a reduction in physiological function which places individuals at risk for future injury. However, while the injury predictive ability of the CKCUEST is becoming known, there is limited information reporting the discriminatory ability of the CKCUEST for persons currently with or without shoulder symptoms²⁸.

Due to the limited reports describing reliability and differences in outcome with physical performance measures between individuals with and without shoulder symptoms, current clinical decision making regarding readiness to return to activity following rehabilitation has a marked shortcoming. Therefore, this study aimed to establish the reliability of traditional upper extremity strength testing and the CKCUEST in persons with and without shoulder symptoms as well as to determine if the testing maneuvers could discriminate between individuals with and without shoulder symptoms. The hypotheses were: 1) the strength testing and the CKCUEST would have excellent test/re-test reliability for both testing groups, and 2) asymptomatic individuals will

demonstrate better performance on the CKCUEST than symptomatic individuals.

Methods

Subjects

Both male and female subjects between 18-50 years of age were recruited for testing. After reading and signing an IRB approved consent form, subjects were screened for placement into one of two groups based on the presence (Symptomatic Group) or absence (Asymptomatic Group) of shoulder symptoms. Presence of pain was determined via the completion of a numeric pain rating scale (NPRS), measured 0-10 with 0 = “no pain at all” and 10 = “worse pain ever felt”. In addition to the NPRS, current physical functional status was assessed with the American Shoulder and Elbow Surgeons Score (ASES) where the patient reported level of perceived function from 0-100, with 0 = “not able to function” and 100 = “best function possible”.¹¹⁸ Inclusion criteria for the Asymptomatic Group required a subject to score 90 or above on the ASES, report no pain or pain no greater than 2/10 on the NPRS, have no limited range of motion, no point tenderness in the shoulder, and no positive examination findings for tissue derangement or other conditions on the screening clinical examination. Subjects with pain ratings $\leq 2/10$ were included in the Asymptomatic Group if the ASES function component was unaffected by the presence of pain (a score of 50 on the function component had to be reported) and the screening would suggest no injury was present. Inclusion criteria for the Symptomatic Group included the presence of pain greater than or equal to 3/10 on the NPRS and an ASES score below 89. Subjects could have limited range of motion but were required to demonstrate active elevation to at least 90°. Subjects may or may not have had point tenderness over their shoulder region and at least one positive clinical

examination finding indicative of tissue derangement and/or other conditions (i.e. tendonitis, subacromial impingement, etc.). Subjects were excluded from this study if they had pain $\geq 8/10$ on the NPRS and an ASES score ≤ 20 . Subjects with pain ratings $\geq 8/10$ were excluded out of concern for possibly advancing any possible underlying tissue lesion or exacerbating their symptoms to the point where the subjects would withdrawal from the study. Subjects were also excluded if they had a current disease, illness, or condition medically disqualifying the individual from participating in vigorous activity, if he or she was currently participating in a post-surgical rehabilitation program, demonstrated signs of cervical radiculopathy¹⁹², or had shoulder and/or neck surgery in the past 24 months. Using a previously published sample size estimation method for reliability studies¹⁹³, the target enrollment for a test/re-test design was 36 total subjects, which is based on an α of 0.05 and β of 0.20. This includes an assumption of a minimum acceptance of 0.70 intraclass correlation for reliability and upper limit acceptance of ≥ 0.90 reliability.

Procedure

Demographic information including name, age, sex, race, height, weight, and history of injury was recorded (Table 1). Following obtainment of the demographic information, a standard shoulder examination was conducted on both shoulders by a single certified athletic trainer with 15 years of clinical experience and expertise in shoulder evaluation and management to verify group assignment. The examination included palpation of anatomical structures of the shoulder and scapula, visual inspection of range of motion, manual muscle testing (break testing without a hand-held dynamometer), and special testing for the confirmation of presence or absence of tissue

injury. The special tests included maneuvers with established acceptable clinical utility and/or those the research team has utilized in clinical practice and have become proficient at employing¹⁹⁴⁻¹⁹⁷. The maneuvers included: Spurling's test, Distraction, and Median Nerve Upper Limb Tension Test for cervical involvement; Painful Arc, Drop Arm Test, External Rotation and Internal Rotation Lag Signs, and Lift-Off Test for rotator cuff involvement; Hawkins-Kennedy and Neer Impingement Signs; Cross Body Adduction Test for AC Joint involvement; Modified Dynamic Labral Shear and Active Compression Tests for Labral involvement; Speed's and Upper Cut Tests for Biceps involvement; and the Scapula Dyskinesis Test for observational detection of altered scapular motion. Following the screening and group allocation, strength testing and the CKCUEST were administered in a randomized sequence.

Isometric Strength Testing of Shoulder Muscles⁶⁹

In order to include a maneuver designed to assess strength that is commonly utilized in clinical practice, isometric shoulder elevation in the plane of the scapula was selected. Each subject was positioned standing with elevation of a single arm to 90° and 30° of horizontal abduction to place the arm in the scapular plane. A hand-held dynamometer (Lafayette Instrument Company, Lafayette, IN) was placed centered on the dorsal aspect of the forearm, half the distance between the distal radius and ulna and the elbow, parallel to the ground. The examiner resisted elevation in the scapular plane with the forearm in neutral and slight supination. In order to standardize the arm position for all subjects, a strap was placed through the handle of the dynamometer and secured to the bottom of a door via a bracket. The strap was adjusted for each subject to account for subject height and arm position as described above (Figure 4.1). The limb to begin with

was randomized. Each trial lasted 5 seconds with each subject instructed to give maximal effort. A minimum of 20 seconds rest was provided between each trial. Each limb was tested 3 times in alternating sequence (i.e. right, left, right, left, etc.) to facilitate strength recovery. The force output was recorded for each trial, with the average of 3 trials for each arm recorded in kilograms for data processing.

1-Repetition Maximum (RM) Estimate of Scaption Strength Test for the Upper Extremity¹⁹⁸

The 1-RM scaption maneuver began with the subject standing and arms resting at the side of the body. Each subject was asked to self-select a free weight that he or she perceived as the maximal amount of weight which could be lifted no more than 10 times to shoulder level. The subjects were permitted to sample various weights in order to assist in selecting the most appropriate load with no more than 3 practice repetitions permitted per each weight sampled. Each subject was asked to elevate the arm up to 90° of elevation which was controlled by a barrier placed at the appropriate height (Figure 4.2). The arm was required to maintain elbow extension during movement throughout the trial. A digital metronome was utilized and set at 47 beats per minute to control the pace of the arm. The pace of 47 beats per minute was established during pilot testing as it was the pace that subjects could accurately and comfortably maintain fluid arm motion. The arm was placed in the plane of the scapula with the subject performing 10 repetitions of scapular plane elevation. Each arm was tested separately for 1 trial. The test was discontinued if the subject could not perform elevation to the required target or if the subject reported pain and/or self-limited him or herself. The subject was stopped by the investigator if observable compensations of the trunk and body were used to lift the

weight. The number of repetitions completed and weight lifted were used to estimate 1-RM via the calculation described by Brzycki¹⁹⁸: Estimated 1-RM = weight lifted/1.0278-0.0278x (where x = the number of repetitions performed)¹⁹⁸. This task was selected because it was considered to be more functional and more challenging than traditional manual muscle testing due to its dynamic design and it allows for the incorporation of an individual's perception of task performance.

Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)¹⁹

The CKCUEST was selected for inclusion in this study because it can be implemented in any clinical setting and is an upper extremity-specific physical performance measure that is not designed exclusively for overhead athletes. Two pieces of tape were placed on the floor parallel to each other 36 inches apart. The subject began in the elevated position similar to a standard push-up with one hand on each piece of tape, the body straight and parallel to the floor, and feet no greater than shoulder width apart (Figure 4.3a). When the test began, the subject removed one hand from the floor, touched the opposing hand on the opposite line and then replaced the hand on the original line (Figure 4.3b). The subject then removed the other hand from the floor, touching the opposite line and returning it to the original line. A single test consisted of alternating touches for 15 seconds. Subjects were instructed to attempt as many touches as possible during the 15 seconds while maintaining proper push-up form. Each subject was permitted to perform a submaximal trial prior to performing the maximal effort attempts in order to become familiar with the test demands. Subjects performed 2 maximal effort trials each lasting 15 seconds with 45 seconds of rest in between the trials. Verbal cues were provided by a member of the research team if a subject was not maintaining proper

body position during the testing. In the event a subject did not return the hand to the tape or did not touch the opposing hand during a repetition, the repetition was not recorded.

The average number of touches between the 2 trials was calculated and recorded.

Data Analysis

Descriptive statistics for all subjects were calculated with means and standard deviations reported for continuous variables and frequencies and percentages reported for categorical variables. The results from both the isometric strength task and the 1-RM estimate task were recorded in pounds then converted to kilograms. The results from all 3 tests were normalized to each subject by dividing each individual's test result by the body weight in kilograms prior to performing any comparative analyses in order to account for anthropometric differences between subjects. The intraclass correlation coefficient (ICC), standard error of measurement (SEM), and minimal detectable change at the 90% confidence level (MDC₉₀) were calculated for all three tasks. In order to examine the inter-session reliability of the maneuvers, subjects were retested following the identical protocol no less than 7 days and no more than 10 days after the initial testing session. ICC values were calculated using the two-way random effects model with absolute agreement [ICC (2,1)]^{199,200}. An ICC greater than 0.75 was interpreted as excellent while values between 0.40–0.75 were considered fair to good and <0.40 was considered poor²⁰¹. Prior to determining if any test could discriminate between subjects with and without shoulder symptoms, a formal test of normality was initially utilized for each dependent variable. The Shapiro-Wilk test for normality was employed revealing the variables were normally distributed which allowed independent t-tests to be utilized for between group comparisons. Statistical significance was set at $\alpha=p<0.05$. All statistical

calculations were performed using STATA/IC (version 13.1 for Windows, StataCorp, LP, College Station, TX).

Results

Subjects

A total of 36 subjects completed both testing sessions with 18 subjects in each group thus satisfying the sample size estimate (Asymptomatic Group: females 10, males 8; Symptomatic Group: females 9, males 9). A summary of the descriptive statistics for all subjects is reported in Table 4.1. Per the ASES self-reported questionnaire, the Symptomatic Group had an average ASES score of 67 ± 15 points out of a possible 100 points. The ASES pain score, function score, and total ASES score were all significantly less for the Symptomatic Group compared to the Asymptomatic Group ($p < .001$). The screening revealed the following diagnoses: possible labral injury (7 subjects), rotator cuff tendonitis/impingement (7), biceps tendonitis (1), rotator cuff injury (1), multidirectional instability (1), and concurrent rotator cuff and labral injury (1).

Reliability

The test/re-test reliability for all three tasks was considered excellent for both groups with the Asymptomatic Group (CKCUEST=0.85, isometric task=0.98 for each arm, 1-RM estimate=0.94 for the dominant arm and 0.96 for the non-dominant) and Symptomatic Group (CKCUEST=0.86, isometric task=0.97 involved arm and 0.95 for non-involved arm, 1-RM estimate=0.93 for each arm) having similar ICC values. The SEM and MDC₉₀ values for each test and group are presented in Table 4.2.

Discriminatory Analysis

Across all tests, prior to normalizing the test results to body weight, there were no

differences in the performance of any task between the Asymptomatic and Symptomatic groups. After applying the body weight correction, neither the isometric task for the dominant/involved arm ($p=.89$) or for the non-dominant/non-involved arm ($p=.99$), nor the 1-RM estimate for the dominant/involved arm ($p=.36$) or for the non-dominant/non-involved arm ($p=.17$) could discriminate between subjects with or without shoulder symptoms (Table 4.3). Subjects with shoulder symptoms had 3% less touches per kilogram of body weight on the CKCUEST compared to subjects without shoulder symptoms but this was not statistically significant ($p=.064$).

Discussion

Clinical decision making for determining the successful completion of a rehabilitation program and thus safe return to activity can be challenging. Clinicians have many tools at their disposal to assist them in making discharge and return to activity decisions, with most clinicians opting to use some variation of a strength measure as a means of determining cessation of treatment or activity readiness. With the understanding that strength measures may not serve as an exclusive surrogate for making discharge and/or return to activity decisions, physical performance measures were developed and have been advocated as more challenging options to determine readiness for activity^{5,16,19,21,202}. Examining both traditional strength measures and an upper extremity-specific physical performance measure in this study led to one of the two study hypotheses being supported with all tasks having excellent test/re-test reliability in both subjects with and without shoulder symptoms. The hypothesis that the CKCUEST could distinguish between individuals with and without shoulder symptoms was partially rejected as the evidence was trending towards supporting the hypothesis ($p=.064$) but was by definition ($p<.05$) not statistically different between the performances of the 2 subject

groups.

All tests could be reliably performed over multiple days amongst individuals with and without shoulder symptoms. Both the isometric strength task and 1-RM estimate had excellent test/re-test reliability with ICC values being ≥ 0.93 . These findings parallel previous studies which have also examined the test/re-test reliability of clinical strength testing of the shoulder⁶⁹. The ICC values in this study for the CKCUEST were slightly lower (ICC=0.85) but still similar to the values reported in the original reliability study (ICC=0.93) and a study involving subjects with subacromial impingement syndrome (ICC ≥ 0.91)^{19,28}. While the original report examining the reliability of the CKCUEST exclusively focused on the outcome of task performance in asymptomatic individuals, the current study chose to also include persons with current complaints of shoulder pain in order to provide a clearer picture of the upper extremity assessment measure's clinical value. Additionally, the original report did not provide SEM and MDC₉₀ values. However, calculation of these metrics could be performed from the original results showing an SEM of 0.5 touch and MDC₉₀ of 1.2 touches¹⁹. The current study's SEM of 2 touches and MDC₉₀ of 4 touches were larger than both the original report¹⁹ and the report involving subjects with subacromial impingement syndrome²⁸. The difference in SEM and MDC₉₀ values was likely due to the performance of 1 less trial in the current study. The decision to utilize 1 less trial was based on the methodology from a recent study¹⁶⁹ and also to lessen the effects of fatigue during testing since multiple tasks were employed.

An important finding from the current study is the lack of a side-to-side difference in the performance of the isometric strength task in the Symptomatic Group. Clinicians

routinely utilize manual muscle testing during initial evaluation procedures or periodically throughout rehabilitation to determine if strength deficits exist or if strength imbalances are resolving. Manual muscle testing was originally employed to assess the strength ability of patients with paralytic conditions²⁰³. In conditions where neurological integrity is compromised, manual muscle testing may have clinical value. However, manual muscle testing may not have robust value as an individual evaluation tool for musculoskeletal injury with an absence of nerve injury or neurological dysfunction. The Symptomatic Group demonstrated no side-to-side difference which can be explained in part as no neurological involvement was reported by these participants. Furthermore, although the subjects in the Symptomatic Group reported a pain level resulting in a significantly lower pain score on the ASES pain score compared to the subjects in the Asymptomatic Group, the subjects with painful shoulders were not actively being treated for their shoulder pain suggesting that pain level is not always equitable to perceived or demonstrated dysfunction. Therefore, it is important to not assume weakness will routinely coincide with the presence of pain.

The dynamic 1-RM estimate was employed to serve as a more challenging variation to the static, isometric strength assessment. Furthermore, acknowledging the paradigm shift from the traditional medical model of healthcare (expert opinion) to the biopsychosocial model (patient as a consumer and active participant in treatment), the utilization of a performance task where the patient was permitted to self-select a weight based on perceived ability to perform was considered to be complementary to the biopsychosocial framework¹⁰⁷. Although the task was deemed appropriate because of the subject-perception aspect, no statistical differences in side-to-side strength were noted in

either group (dominant to non-dominant arm in the Asymptomatic Group and involved to non-involved arm in the Symptomatic Group). To assist in the selection of the appropriate weight, the subjects were permitted to sample various weights and to perform no more than 3 practice repetitions prior to finalizing their decision on the weight to use for the full 10 repetition trial. However, although the weights could be sampled to enhance appropriate load selection, the lack of difference between the arms during the 1-RM estimate task creates the possibility that some individuals may have underestimated the amount of weight that could be lifted a maximum of 10 repetitions.

Although the 3 tasks could be reliably reproduced by the 2 groups over multiple days, the tests could not distinguish performance outcome between individuals with and without shoulder symptoms. The CKCUEST was trending towards being able to distinguish between the 2 groups (where $p=.064$) suggesting the more involved physical performance measure may provide clinicians with different information than the traditional strength measures regarding the ability to perform. While Tucci et al found a distinct difference in the number of CKCUEST touches performed between subjects with (10-12 touches) and without (23-28 touches) subacromial impingement syndrome, the subacromial impingement syndrome subjects were 24 years older on average compared to the healthy group. Therefore, the difference between the groups could have been due to age rather than injury presence which limits the interpretability and comparability of the findings to the current study²⁸.

Unlike the lower extremity which is sensitive to the effects of injury because of the impact injury can have on stability and mobility, the upper extremity has the advantage of having a separate and independent non-involved extremity which can be

utilized for task performance. This phenomenon was demonstrated in the current study where the non-involved arm of the subjects in the Symptomatic Group outperformed the non-dominant arm of the subjects in the Asymptomatic Group by 1.5kg (which equates to an approximate difference of 3 pounds). Although not statistically different, the 1.5kg difference may suggest that the individuals with shoulder symptoms have learned to adapt and modify task performance by utilizing the non-involved arm in a more efficient manner. The decreased effect of injury on the upper extremity is further highlighted in the medical impairment rating literature where the ratings for an injured arm have higher thresholds than the similar impairment ratings for an injured knee²⁰⁴. For example, an 8% upper extremity impairment equates to a 5% whole body impairment rating while an 8% lower extremity impairment equates to a 20% whole body impairment rating²⁰⁴. It is therefore possible that a general measure of physical performance such as the CKCUEST may help overcome the shortcomings of traditional strength testing as a metric for determining return to activity because of its more challenging requirements thus giving it the ability to potentially better distinguish between persons with and without shoulder symptoms. It is not suggested that traditional strength testing be eliminated from physical assessments because they can have value with detecting certain pathological conditions i.e. rotator cuff injury^{205,206} but should be reconsidered as clinical measures for determining cessation of treatment and/or activity readiness.

Finally, the upper extremity physical performance measure literature has suggested that a testing battery may better assist clinicians in making well-informed clinical decisions about the complex upper extremity and return to activity^{5,202}. While this observation has merit, the composition of the testing battery has yet to be established.

Recently, Pontillo et al employed an upper extremity pre-season testing battery comprised of isometric strength measures, fatigue tasks, and the CKCUEST in an attempt to predict the occurrence of shoulder injury sustained during a competitive football season¹⁶⁹. They found that although isometric forward elevation strength and prone-Y to fatigue performance in pre-season were predictive of future injury to the right arm, the CKCUEST was the only maneuver predictive of injury to either arm with a clinical utility of 0.79 sensitivity, 0.83 specificity, and 18.75 positive likelihood ratio¹⁶⁹. These findings are in contrast to the findings in the current study where the CKCUEST could not clearly discriminate between individuals with and without shoulder symptoms. This contrast however is likely due to differences in the timing of testing (the subjects with shoulder pain in the current study have been experiencing pain from months to years rather than acutely) and the variation in diagnoses identified in each study. Specifically, the current study included diagnoses strictly based on clinical examination without imaging where only half of the population had suspected internal derangement, while the diagnoses reported by Pontillo et al were primarily cases of instability with verified labral lesions and acromioclavicular separations¹⁶⁹.

Limitations

There are several limitations to note in this study. First, the Symptomatic Group was comprised of individuals with various diagnoses. Although the various conditions could allow the results to be generalized, focusing on a specific pathology or condition may have yielded different results. Additionally, none of the subjects were evaluated by a physician and thus no advanced imaging or diagnostic testing (i.e. nerve conduction, diagnostic arthroscopy, etc.) was performed to verify the extent of tissue derangement

(assuming any existed). Second, the 1-RM estimate procedure allowed for each subject to self-select the weight he or she perceived as the maximum weight which could be lifted for 10 repetitions. It is possible that some subjects underestimated the weight that could have been lifted and thus limited the chance of finding differences within or between subjects. Third, the closed chain design of the CKCUEST may not provide specific information regarding the ability to perform open chain tasks such as overhead throwing with success. However, the CKCUEST appears to provide different information compared to traditional strength testing highlighting the idea that physical performance measures may allow for the simultaneous assessment of multiple physiological systems better than strength testing. The higher demands of the CKCUEST are likely producing the difference in information but may be one of multiple metrics to utilize for upper extremity performance. Finally, strength was the primary physiological component of physical function that was examined in this study. It is understood that multiple areas of physical function or performance should be considered since human task execution rarely, if ever, utilizes just one component of function during performance. However, strength was the main area of focus since it is commonly considered during the evaluation and rehabilitation of musculoskeletal injury.

Conclusions

Similar to previous literature, the strength tasks and physical performance measure examined in this study were found to have excellent test/re-test reliability. The excellent test/re-test reliability has now been expanded to include individuals with various reasons for shoulder symptoms. Traditional strength testing does not appear to be the ideal assessment method to utilize for making discharge and/or return to activity decisions due to the lack of performance differences between the testing groups.

Although the tests could be reliably performed, no test could clearly distinguish between individuals with and without shoulder symptoms however; the CKCUEST could have a role as a task to determine readiness to return to activity as it was trending towards being able to discriminate between known groups. Further research needs to exclusively examine specific pathological conditions such as labral injury, rotator cuff injury, and instability to confirm the maneuver's clinical utility in patients with distinct diagnoses as well as in overhead athletes.

Table 4.1. Subject Demographics for Asymptomatic and Symptomatic Groups (N=36)

	Asymptomatic Group (Mean ± SD)	Symptomatic Group (Mean ± SD)
Total Subjects	18	18
Age	29 ± 7 years	30 ± 8 years
Height	171 ± 7 cm	172 ± 12 cm
Weight	71 ± 14 kg	76 ± 15 kg
Sex		
Male	8	9
Female	10	9
ASES Pain Score		
D/I Arm*	49 ± 2	29 ± 9†
ND/Ni Arm*	50 ± 0	49 ± 4
ASES Function Score		
D/I Arm*	50 ± 1	38 ± 10†
ND/Ni Arm*	49 ± 1	48 ± 3
ASES Total Score		
D/I Arm*	99 ± 2	67 ± 15†
ND/Ni Arm*	99 ± 1	98 ± 6

ASES=American Shoulder and Elbow Surgeons; SD=standard deviation; cm=centimeters; kg=kilograms; D/I=Dominant/Involved; ND/Ni=Non-Dominant/Non-Involved

*Involved and non-involved arm for the Symptomatic Group paralleled dominant and non-dominant arm for the Asymptomatic Group

†Symptomatic Group scores significantly less than Asymptomatic Group scores P<.001

Table 4.2. Reliability Results for Asymptomatic and Symptomatic Groups

Asymptomatic Group n=18	Isometric Task Dominant	Scaption Non-Dominant	CKCUEST	1-RM Estimate Dominant	1-RM Estimate Non-Dominant
ICC	0.98	0.98	0.85	0.96	0.94
95% CI Lower Bound	0.95	0.95	0.42	0.89	0.82
95% CI Upper Bound	0.99	0.99	0.95	0.99	0.98
Mean	12kg	12kg	22 touches	8kg	8kg
SD	4kg	4kg	5 touches	4kg	4kg
SEM	1kg	1kg	2 touches	1kg	1kg
MDC ₉₀	1kg	1kg	4 touches	2kg	2kg
Symptomatic Group n=18	Isometric Task Involved	Scaption Non-Involved	CKCUEST	1-RM Estimate Involved	1-RM Estimate Non-Involved
ICC	0.97	0.95	0.86	0.93	0.93
95% CI Lower Bound	0.91	0.86	0.11	0.81	0.83
95% CI Upper Bound	0.99	0.98	0.96	0.98	0.98
Mean	12kg	13kg	22 touches	10kg	10kg
SD	4kg	4kg	5 touches	4kg	5kg
SEM	1kg	1kg	2 touches	1kg	1kg
MDC ₉₀	2kg	2kg	4 touches	3kg	3kg

CKCUEST=closed kinetic chain upper extremity stability test; RM=repetition max; ICC=intraclass correlation coefficient; 95% CI=95% confidence interval; SD=standard deviation; SEM=standard error of measurement; MDC₉₀=minimal detectable change at 90% confidence level; kg=kilogram

Table 4.3. Task Results Normalized to Body Weight (in kilograms) for Asymptomatic and Symptomatic Groups

	Asymptomatic Group (n=18)	Symptomatic Group (n=18)	P-Value (95% CI)
Isometric Task D/I	16% ± 4%	16% ± 3%	P=0.89 (15%, 17%)
Isometric Task ND/NI	16% ± 4%	16% ± 4%	P=0.99 (15%, 17%)
CKCUEST	32% ± 7%	29% ± 6%	P=0.064 (29%, 32%)
1-RM Estimate D/I	12% ± 4%	12% ± 4%	P=0.36 (11%, 13%)
1-RM Estimate ND/NI	12% ± 4%	13% ± 4%	P=0.17 (11%, 13%)

CKCUEST=closed kinetic chain upper extremity stability test; RM=repetition max; 95% CI=95% Confidence Interval; D/I=Dominant/Involved; ND/NI=Non-Dominant/Non-Involved

Figure 4.1. Isometric Strength Testing in Scaption



Figure 4.2. 1-RM Estimate Testing



Figure 4.3a. Beginning position for the Closed Kinetic Chain Upper Extremity Stability Test



Figure 4.3b. Active position for the Closed Kinetic Chain Upper Extremity Stability Test



Chapter Five: Comparing Baseline Physical Function to Physical Function after Rehabilitation for Musculoskeletal Injury

Introduction

Patient-reported outcome measures (PROs), which allow clinicians to obtain a patient's perspective in regards to the ability to perform activities in the context of disability, dysfunction, or impairment^{37,54}, and physical performance tests, which allow patients to demonstrate their ability to perform physical tasks, provide useful but limited information related to physical function. Taken individually, each assessment method only provides a portion of information to be utilized when designing rehabilitation programs⁵. Recent opinions have advocated for a comprehensive approach to evaluation and rehabilitation that combines the perspective of the patient and the clinical measures employed by clinicians in order to yield more complete patient-specific information thus leading to improved rehabilitation outcomes^{5,13,38}.

Physical function can be positively or negatively impacted by various factors, with positive results being considered successful recovery and negative results being termed "disablement". Disablement models were developed because they attempt to account for some if not all of these influential factors by putting the disease in context to the individual rather than assuming all persons are affected similarly by the condition⁵⁵⁻⁵⁹. These models complement a recognized paradigm shift in modern day healthcare from a biomedical focus highlighted by experts (i.e. clinicians) controlling the information collected and disseminated for clinical decision making, to the social focus where the patient is an active participant in the treatment decision making process¹⁰⁷. However, as useful as these models are at contextualizing the impact of disease on an individual patient, they do not specifically point clinicians towards areas of rehabilitation that

should be addressed for a specific patient. In an attempt to overcome this shortcoming of existing disablement models, a conceptual model known as the Optimum Outcome Model which describes multiple factors that influence a rehabilitation outcome was developed⁶⁰. The model details 3 specific components (patient factors, clinician factors, and external factors) that should be addressed during the rehabilitation of musculoskeletal injury (Figure 5.1).

The Optimal Outcome Model⁶⁰ allows clinicians to address areas of needed improvement for a single patient while attempting to achieve balance amongst the many rehabilitation related factors. The model helps to illustrate that it is the responsibility of the clinician to begin the rehabilitation process by putting the condition in context to the individual patient (accomplished with PROs and subjective history notation) while adding in complementary pieces such as clinical (impairment measures of strength, range of motion, girth, physical performance testing, etc.) and external factors (returning the patient to pre-injured levels of activity) in order to create balance amongst the influential factors to achieve the best possible outcome. However, this information is traditionally obtained after injury has occurred and dysfunction has set-in, placing physical limitations on the patient. Considering that a common goal in musculoskeletal rehabilitation is to return the patient to pre-injured levels of activity^{3,29,36,99,156,183,207,208}, an assessment of pre-injury physical function could provide insight to each individual person's specific concerns and potential goals. Therefore, measuring patient-perceived and demonstrable physical function not only prior to the beginning of rehabilitation but also *prior* to the occurrence of injury may help limit possible strains on one or more of the components within the Optimal Outcome Model.

Determining return to pre-injured levels of play following athletic injury can be challenging as many factors can affect the return to play decision^{3,36,209}. Ardern et al²¹⁰ have suggested that return to sport can be affected by physical, psychological, and social influences – collectively known as biopsychosocial influences – which in turn can affect functional performance positively or negatively affecting return to sport. It is possible that these many influential factors of the return to sport decision have led to the inconsistent rates of return to pre-injured levels of activity in the existing literature^{29,99,100}. Furthermore, critical review of that same literature has revealed a prominent gap in that baseline measures of pre-injured levels of activity, either perceived or demonstrable, were not obtained, calling into question if pre-injured activity levels were truly achieved^{29,99,100}. An additional gap would be that continuous follow-up data such as functional status at discharge and at subsequent time points have not been reported. The majority of currently available data is cross-sectional data reported a 1 or 2 year post injury without interim data points. These long-term follow-up periods may not be providing relevant information regarding an athlete's ability to participate in sport at the time of return. The lack of short term follow-up of an athlete's ability to physically function at the time of discharge places clinicians at a disadvantage for effectively monitoring the functional status of competitive athletes. It is possible these athletes may not have reached their actual pre-injured levels of activity and placing them at risk for re-injury or subsequent injury to other body regions.

An example of a negative consequence that may occur would be athletes beginning a competitive season with lower perceived physical function. Authors have reported that lower levels of perceived physical function exist in athletes and military

cadets with a previous injury history prior to the beginning of a competitive season although they successfully passed physical examinations to participate in activity^{90,211}. In other words, previous experiences can affect future functional status. It is reasonable to postulate that although documented change in perceived or demonstrable physical function may have large shifts in a positive direction following an intervention, physical function may not have reached actual baseline levels especially when previous experiences (i.e. previous injury) are considered. Consequently, since it is currently the standard of practice to not routinely obtain or utilize true baselines of relative, pre-injured physical function, it is unclear whether a true causal link can be established between rehabilitation and the restoration of pre-injured physical function. Furthermore, exclusively focusing on anatomy and physiology while not incorporating patient perception as part of the evaluation and treatment process is contrary to the individualized care model that modern healthcare strives to follow. As such, it is reasonable to theorize that a framework such as the Optimal Outcome Model that accounts for the patient, clinician, and external factors within the rehabilitation process could be utilized to increase the occurrence of positive treatment outcomes i.e. return to pre-injured levels of activity. However, since it is unknown if pre-injured levels of activity are actually restored following rehabilitation of musculoskeletal injury, it would be crucial to determine the natural history of perceived and demonstrable physical function as the initial step in testing different aspects of the Optimal Outcome Model. Therefore, the primary purpose of this study was to obtain baseline values of pre-injured physical function and determine if and when athletes return to those baseline levels of perceived and demonstrable physical function following musculoskeletal injury. The

secondary purpose was to determine if history of injury affects perceived and demonstrable physical function at the return to activity time period. The hypotheses were: 1) that athletes that return to sport following an injury will not have a significantly lower level of physical function compared to their pre-season baseline level of physical function and 2) that athletes with a history of injury will have significantly lower perceived and demonstrable physical function scores compared to athletes without a history of injury.

Methods

Study Population

Inclusion for Baseline

Male and female collegiate athletes participating in a National Collegiate Athletic Association or National Association of Intercollegiate Athletics sanctioned sport and who were medically cleared by a team physician for full participation were recruited to participate in this study. The following inclusion criteria were required in order to participate in the study: Ages 18-35; ability to read, speak, comprehend English; and medically cleared to participate in athletics (per physician determination during pre-season physical examination). Subjects were excluded if they had a current disease, illness, or condition medically disqualifying the individual from participating in competitive athletics and/or a current musculoskeletal injury preventing them from going through baseline testing and preventing full participation in athletics.

Procedures Purpose 1: Baseline Assessment

During the athletic pre-season time period, prior to the first practice, the following procedures were followed: Potential subjects were approached during pre-season physical examinations conducted at pre-determined school athletic facilities and were

provided an informed consent form to read and sign. Two collegiate institutions were included as collection sites. Members of the research team collected demographics including name, age, sex, race, height, weight, sport, years playing sport, and history of injury to the shoulder, elbow, knee, or ankle. These four joints were targeted as they represented 85% of all injuries that occurred in the previous year at the collegiate institutions. In order to obtain subject perception regarding his or her ability to physically function, the research team distributed paper versions of the Kerlan Jobe Orthopedic Clinic Shoulder and Elbow Score (KJOC)⁵¹, Knee Injury and Osteoarthritis Outcome Score (KOOS)⁴⁶, and the Foot and Ankle Disability Index (FADI)¹³⁵ PROs (Appendix I: Data Collection Forms and Surveys). The following minimal detectable change values were utilized for this study: KJOC (shoulder injury) = 9 points⁵¹, KJOC (elbow injury) = 7 points⁵¹, KOOS pain (PN) = 6 points²¹², KOOS symptoms (SX) = 9 points²¹², KOOS sport and recreation function (SP) = 12 points²¹², KOOS knee-related quality of life (QL) = 7 points²¹², FADI = 5 points^{48,213}, and FADI Sport = 10 points^{48,213}. Following completion of the questionnaires, each subject performed the following 3 dynamic physical performance tests in random order.

Closed Kinetic Chain Upper Extremity Stability Test¹⁹

The set-up for the closed kinetic chain upper extremity stability test (CKCUEST) requires two pieces of tape placed on the floor parallel to each other 36 inches apart. The subject assumed the up position of the push-up, with one hand on each piece of tape and the body straight and parallel to the floor. The subject was instructed to remove either hand from the floor, touch the opposite line and then replace the hand on the original line. The subject then removed the other hand from the floor, touched the opposite line and

returned it to the original line. The sequence of alternating touches occurred for 15 seconds with the goal of performing as many touches as possible during the time allotted. Subjects performed 2 trials each lasting 15 seconds with 45 seconds of rest in between trials. The average number of touches between the 2 trials was recorded¹⁶⁹. The original description of the CKCUEST reported the completion of 3 trials¹⁹. The decision to utilize 1 less trial was based on 2 reasons: 1) the methodology from a recent study utilized 2 trials for the CKCUEST in an athletic population¹⁶⁹ and 2) because the CKCUEST would eventually be employed at the end of the rehabilitation process following musculoskeletal injury, it was possible that pain and/or muscle soreness may be present therefore an attempt was made to lessen the effects of these negative sensations. In a previously published study, members of the research team found the CKCUEST to have excellent test-retest reliability in persons with (ICC=.85) and without (ICC=.86) shoulder symptoms²¹⁴.

Single Leg Hop for Distance¹²³

Subjects performed a single leg hop for distance with each lower extremity. After demonstration by the investigators, each subject was allowed up to 5 practice attempts prior to recording the official trials. Beginning with the heel of the test leg directly on the beginning edge of the starting line; subjects performed one hop forward for maximal distance to complete a trial. The hop was measured from the beginning edge of the starting line to the heel of the foot after completion of a trial. Each limb was tested 3 times with the average distance scored for each limb. This test was selected because it is a widely used maneuver which has shown to have adequate test/re-test reliability^{26,67,151}.

Dynamic Balance¹⁴⁴

Dynamic balance was assessed with a portion of the star excursion balance test (SEBT). In unpublished work, the anterior reach was most correlated with injury prediction therefore only this direction was performed by each subject. Participants were instructed to stand on one leg with the toes positioned at the front edge of a tape measure secured to the floor. Participants maintained single limb stance as best as they could with their hands on their hips. They were instructed to reach forward with the opposite limb along the tape measure and touch down gently with their toes on the farthest part of the line they could reach. They returned to their starting position prior to performing the next trial. Each subject performed three trials for each leg. If a subject touched down with a significant amount of body weight with the reaching limb, the trial was discarded and repeated. The length of the reach in the anterior direction was marked and recorded. SEBT measures were normalized to each subject's leg length and reported as a percentage of length in centimeters.

All physical performance tests were selected due to their clinical applicability and their routine use in clinical practice. Additionally, the subject population was comprised of athletes who participated in a variety of sports. Therefore, the physical performance tests were believed to be generalizable to the various types of athletes. All physical performance tests were administered in a randomized, serial format with 2 stations being set-up for each test in order to expedite the testing process. The minimal detectable change values used in this study for the physical performance tests were: CKCUEST = 5 touches²¹⁴, Single Leg Hop = 12cm²¹⁵, and SEBT = 6% leg length²¹⁶.

Procedures Purpose 2: Post Injury Assessment

The completion of preseason physical examinations and the commencement of the first organized team practice marked the beginning of the study monitoring period. The definition of injury utilized in this study was noted to be “a musculoskeletal condition sustained by an athlete that affects the athlete’s participation or performance in sports, games, or recreation where medical attention was sought and at least 1 day of organized team activities was missed due to the injurious event”. The event of interest had to occur as a result from participation in organized athletic activities as part of the athlete’s participation in organized team events (practices, strength/conditioning training, scrimmages, and games). The medical attention definition has been advocated for organizations who have routine access to medical care which was the case for the three universities participating in this study⁷². If injury about the shoulder, elbow, knee, or ankle occurred, the research team was notified by the sports medicine staff and the athlete was contacted by a member of the research team. The athlete was asked to complete only the patient-reported outcome questionnaire applicable to the injured extremity to determine if any change occurred from baseline testing to the time of injury. The questionnaire was completed via Research Electronic Data Capture (REDCap), an electronic survey instrument platform (NIH CTSA UL1TR000117) or via a hard copy of the appropriate questionnaire based on each athlete’s preference. The treating clinicians followed their established standard of care for treating each injury without deviation or modification from established protocols. The clinicians who treated the subjects following injury were blinded from all results of subjective and objective testing until the end of the study. The blinding was performed in order to avoid potential Hawthorne

effects where the treating clinicians may possibly deviate from their standard of practice for treating musculoskeletal injuries due to the presence of the research team. Once treatment was completed, the sports medicine staff informed the research team when the athlete had been discharged and ready to return to activity. Following discharge, each subject was asked to complete the same subjective questionnaires and physical performance tests as performed during pre-season physical examinations (only for the extremity which was injured i.e. shoulder/elbow injury = KJOC and CKCUEST; knee injury = KOOS, single leg hop, and SEBT; ankle injury=FADI/FADI Sport, single leg hop, and SEBT).

After return to sport occurred, each subject was contacted at 1 month, 3 months, and 6 months following return to activity and asked to complete the patient-reported outcome measure specific to his or her recent injury. The PROs were completed until 6 months post-injury in order to determine long-term athlete perception of recovery. The subjects were asked to complete the objective testing until the values were at least within the established minimal detectable change for each metric.

Statistical Analyses

Descriptive/summary statistics were performed for all demographic variables and were reported as means and standard deviations for continuous variables such as age, time playing sport, height, weight, body mass index, and days missed for injury while counts and percentages were utilized for sex and history of injury. The distribution of data for each functional variable was assessed for normality using the Shapiro-Wilk test for normality. To assess the primary purpose of this study which was to determine if athletes return to baseline levels of perceived and demonstrable physical function following musculoskeletal injury, separate Mann-Whitney U sign rank non-parametric

tests were employed for each anatomical joint due to the lack of normally distributed data. Additionally, the data was not normally distributed for the secondary purpose which directed the research team to employ Mann-Whitney U rank sum non-parametric tests to compare subjective scores and physical performance test results between subjects with and without a history of injury. Alpha was set at $p < .05$ for all comparisons. All statistical calculations were performed using STATA/IC (version 13.1 for Windows, StataCorp, LP, College Station, TX).

Results

Baseline information was obtained from 365 collegiate athletes (154 females, 214 males) representing 14 different sports. A history of 458 previous injuries were present in 365 athletes. Previous injury to specific joints were further identified to occur in the shoulder (23%), elbow (8%), knee (34%), and ankle (61%).

Pre-season data and injury data was collected from August 2015 until July 2016. A total of 48 injuries occurred during the study period. Three (6%) subjects sustained a shoulder injury, four (8%) subjects sustained an elbow injury, 17 (35%) subjects sustained a knee injury, and 24 (50%) subjects sustained an ankle injury. Of the 48 injuries, three (6%) resulted in subjects undergoing surgery and three (6%) subjects chose to leave school due to the injury, none of which returned to sport during the monitoring period. The 42 remaining subjects all were treated by their respective athletic trainer, discharged from care, and returned to sport during the monitoring period with 41 of the 42 subjects appearing in at least one game after return. The one subjects who did not record a game statistic was a freshman who was not a starter. Game participation was at

the discretion of the coach and represents an external factor for an athlete who returned to sport.

Shoulder and Elbow Injuries

The shoulder injuries included 1 clavicle fracture, 1 acromioclavicular joint separation (grade 2 Rockwood classification)²¹⁷, and 1 superior labral injury. All of these subjects returned to sport participation (11-45 days) during the season. The median KJOC values for the 3 subjects were: baseline=89, initial injury=50, discharge=70, and 1 month follow-up=99. The subjects could not be reached to complete the KJOC at the 3 and 6 month follow-up time points. The KJOC scores at the initial injury and discharge time periods were significantly reduced from the baseline time period ($p<0.001$) and were beyond the established minimal detectable change value of 9 points. Two of the 3 subjects had a previous shoulder injury. The subjects who sustained the clavicle fracture previously injured the contralateral shoulder while the subjects who sustained the acromioclavicular joint injury previously injured the same shoulder.

The elbow injuries included 1 elbow contusion and 3 ulnar collateral ligament disruptions. Only the subjects suffering an elbow contusion returned to sport and did so in 4 days after injury. Two of the ulnar collateral ligament disruptions were surgically reconstructed and have not been discharged to return to sport as of yet. One subject decided to leave school as a result of the UCL injury. There was a lack of complete data for these subjects due to the small sample who sustained an elbow injury therefore; subjective and objective data are not presented for these injuries.

Knee Injuries

Demographic information for the 17 subjects who sustained a knee injury during the competitive season is provided in Table 5.1. Subjects missed between 2-22 days of activity due to a knee injury. Median values for the KOOS subscales at each time period are reported in Table 5.2. All scores were significantly reduced from baseline to the initial injury time point ($p \leq 0.01$). Subjective and objective scores at the discharge, 1 month, 3 month, and 6 month post return time points were not statistically different from the baseline time period except for the KOOS QL score which had a 25 point deficit at discharge ($p=0.01$). A 15 point deficit existed for the KOOS SP score at the discharge time point which was beyond the minimal detectable change of 12 points however, this was not statistically significant ($p=0.10$). All KOOS subscale scores were within minimal detectable change and/or equitable to baseline scores by the 1 month follow-up time period.

Ten of the 17 athletes who sustained a knee injury during the study period had a history of previous knee injury. When comparing the median KOOS scores for subjects who had sustained a previous knee injury to subjects who did not have an injury history at each time point, those with an injury history reported significantly lower KOOS scores for all subscales to begin the season ($p \leq 0.04$) (Table 5.3). KOOS scores did not statistically differ between the groups at the initial injury time point while only the KOOS SP scores were trending towards significance ($p=0.06$) for subjects with a previous knee injury at the discharge time point (KOOS SP scores were 20 points lower in the previously injured subjects). The previously injured subjects had notably decreased KOOS SP and KOOS QL scores at 1 month follow-up (20 and 25 point decrease

respectively) as well as notable decreases in all KOOS subscale scores at the 3 and 6 month follow-up time points. There were no statistical differences between the groups for single leg hop or SEBT performance at any time point.

When comparing the KOOS scores to the baseline time point within each group, all scores significantly decreased at initial injury ($p \leq 0.05$) except for the KOOS SX score for the subjects with a previous knee injury ($p=0.17$) (Table 5.3). All scores at the initial injury time point were beyond the established minimal detectable change values. The KOOS SX and KOOS QL median scores were beyond minimal detectable at the discharge time point for both groups however, only the KOOS QL scores were significantly different for each group ($p=0.05$). The KOOS PN scores at discharge for subjects without a previous knee injury were significantly lower compared to the baseline values ($p=0.05$). Additionally, the KOOS SP score at 6 month follow-up and the KOOS QL scores at all time points for the subjects with a previous knee injury were beyond minimal detectable change. The SLH was significantly reduced at discharge compared to the baseline time point ($p=0.03$) for subjects with a previous knee injury while there were no statistical differences for the SEBT performance at any time point. The SLH exceeded the baseline value at the 1 month follow-up time period (180cm vs. 176cm) which was trending towards being significantly different ($p=0.06$).

Ankle Injuries

Demographic information for the 24 subjects who sustained an ankle injury during the competitive season is provided in Table 5.4. Subjects missed between 2-95 days of activity due to ankle injury. Median values for the FADI and FADI Sport are reported in Table 5.5. FADI and FADI Sport scores were significantly reduced at the

initial injury and discharge time periods compared to the baseline time period ($p \leq 0.01$) however, only the FADI scores were beyond minimal detectable change at the discharge time period. There was no statistical difference in the performance of either physical performance task at any time period compared to baseline although, the single leg hop values at the 1 month time period exceeded the baseline and discharge values.

Eighteen of the 24 athletes who sustained an ankle injury during the study period had a history of previous ankle injury. When comparing the median FADI and FADI Sport scores for subjects who had sustained a previous ankle injury to subjects who did not have an injury history at each time point, there were no statistical differences in subjective or objective scores between subjects with and without a history of previous ankle injury (Table 5.6). The subjects with a previous ankle injury had 7% greater SEBT anterior reach values compared to subjects who did not previously experience an ankle injury however this was not statistically significant ($p=0.09$).

When comparing the FADI and FADI Sport scores to the baseline time point within each group, all scores significantly decreased at the initial injury time point ($p \leq 0.03$). These values were beyond minimal detectable change. The FADI and FADI Sport scores were significantly decreased at the discharge time point for the subjects who had a history of ankle injury (4 and 2 points respectively). The subjects who did not experience a previous injury had decreased FADI (9 points) and FADI Sport (4 points) scores at the discharge time point as well however these scores were not statistically significant. The single leg hop values at the 1 month time point for the subjects with a previous ankle injury exceeded the baseline values which was trending towards being statistically significant ($p=0.06$). While not statistically significant, the SEBT anterior

reach was decreased at the discharge time point compared to the baseline time point for subjects without a previous ankle injury. The decreased SEBT value achieved minimal detectable change of 6% leg length.

Discussion

The primary hypothesis that collegiate athletes would not have significantly different perceived and demonstrable physical function between baseline and discharge time points was partially confirmed as scores for 2 subscales of the KOOS (SX and PN) and both single leg hop and anterior reach of the SEBT physical performance task results were similar to baseline values at discharge. However, the KOOS SP, KOOS QL, FADI, and FADI Sport scores were significantly reduced at discharge compared to baseline values. The primary aspects of the rehabilitation process tend to be directed towards reducing pain and symptoms following injury (rest, cryotherapy, immobilization, anti-inflammatory medications, etc.) therefore; it is not surprising the KOOS SX and KOOS PN subscales were restored to baseline values at the discharge time period. Additionally, the treating clinicians were making sound clinical decisions about when to discharge an athlete from formal supervised rehabilitation as highlighted by 1) the athletes' return to team activities in the same season and 2) the lack of re-injury or injury exacerbation during the study period²¹⁸. It is possible that an additional injury could occur later in the athletes' careers^{71,73,96} however re-injury in the same season was not a concern in this cohort.

Conversely, the lower KOOS SP and KOOS QL scores at the discharge time period may be due to an inability to simulate the exact conditions and demands of each specific sport as well as the requirements for each individual in the controlled

rehabilitation setting⁵. Although sport-specific activities could have been implemented as part of the rehabilitation for the subjects who sustained a knee injury, it is possible that the lower KOOS SP scores could have occurred as a result of the difference in environment and demands between the treatment facility and the practice environment. The lower KOOS SP and KOOS QL scores that existed after return to sport was permitted possibly highlights a need to assess these components at a greater frequency compared to 1 or 2 year follow-up following return to sport i.e. monthly or bi-monthly in order to properly determine when athletes perceive their ability to physically function as appropriate.

It is also possible that there could be a negative psychological component affecting the treatment outcome. For example, collectively, the subjects who experienced a knee injury during the monitoring period had lower KOOS QL scores at discharge but no difference in physical performance measure results. This finding is not unique as previous authors have found that athletes can successfully perform physical tasks following knee joint surgery but have marked psychological concerns such as a fear of re-injury¹⁰⁰. However, the previous work identified the existence of fear of re-injury while the current study identified that the question that generated the lowest result on the KOOS QL was “How often are you aware of your knee problem?” with the respondents often answering “weekly”. It should also be noted that the subjects in this study primarily sustained low grade sprains and strains with most subjects returning to sport within the same season whereas the subjects in the previous work underwent ACL reconstruction. Although the injuries sustained in the current study were mostly low grade injuries that allowed for return to activity to occur within 2-3 weeks from the onset

of the injurious incident, a level of self-reported disability in physical function still existed following return to sport which mimics phenomenon described in a recently developed conceptual return to sport (RTS) model. Ardern et al²⁰⁹ identified 3 levels in the RTS model that could describe an athlete's functional status following return from injury. The first level, return to participation, is where an athlete may be in active rehabilitation, modified training, or have returned to sport but is currently below the target level of participation i.e. not ready to return to full participation for medical, physical, or psychological reasons. The second level, return to sport, is when an athlete has returned to a specific sport but is not performing at his or her desired level. The final level, return to performance, is when an athlete has returned to sport and is performing at or above the pre-injured level of activity. Based on this conceptual model²⁰⁹, it is possible that the discrepancy between task performance and subject perception identified in the current study should be considered an anticipated occurrence for athletes recovering from musculoskeletal injuries. Furthermore, the results provide justification for clinicians to utilize a comprehensive assessment approach comprised of both patient perception and task demonstration to make clinical decisions regarding the status of patient physical function^{5,13}. If either the subjective assessment or objective assessments were used as the sole means of determining readiness to return to sport, interpretation of the results would be considered incomplete.

Ankle injuries commonly occur in athletics¹, however, limited information exists about patient-reported outcome results for ankle sprains^{48,141,213}. The subjects who sustained an ankle injury during the study period had lower self-reported FADI and FADI Sport scores at discharge compared to their baseline values. Although this difference was

statistically significant, the 6 point difference in the FADI was just beyond the minimal detectable change of 5 points while the 3 point difference in the FADI Sport was not beyond minimal detectable change of 6-10 points^{48,213}. Therefore, this may be an example of statistical difference not equating to clinical meaningfulness. It is interesting that the subjective results derived from the FADI and FADI Sport were of lower magnitude compared to the results derived from the KOOS. However, there are 2 potential explanations for this occurrence. First, 96% of the subjects who sustained an ankle injury during the study monitoring period were diagnosed with a low-grade ligament sprain while the subjects who sustained a knee injury included diagnoses of muscle injuries (41%) and ligament/cartilage injuries (59%). The less severe, homogeneous ankle injuries may have led to lower reports of dysfunction on the FADI and FADI Sport. Second, it is also possible that the differences in design between the FADI questionnaires and the KOOS subscales contributed to the different outcomes. The FADI and FADI Sport specifically ask 30 of 34 questions related to an individual's ability to perform tasks with 4 questions related to pain. The KOOS is comprised of 7 questions focused on symptoms, 9 related to pain, 5 for sport activities, and 4 questions specific to quality of life. It is possible that the different constructs being assessed generated different levels of perceived physical function.

The secondary hypothesis was also partially confirmed as subjects with a previous knee injury had lower KOOS scores compared to subjects without a previous knee. Since previous injury has been recognized as a predictor of future injury in the shoulder and knee^{70,85-92}, screening for a history of injury during the pre-season time period was a pertinent component of functional assessment prior to athletic participation. Identifying a

history of previous knee injury as a deleterious factor for current PRO score parallels studies performed among United States Military Academy freshman cadets and also National Collegiate Athletic Association Division I and III collegiate athletes^{50,211}. In these previous studies and the current, KOOS SP and KOOS QL scores suffered the greatest deficits among those subjects with a history of knee injury yet all subjects in both the current study and the previous work were medically cleared to participate in organized team activities. Furthermore, the athletes who sustained a previous knee injury prior to the study monitoring period had decreased KOOS QL scores from the initial injury to 6 month follow-up time points that were beyond minimal detectable change thresholds. The consistency of these findings demonstrate that although athletes may pass physical examinations during pre-participation screenings allowing them to participate in sport, some athletes may report having persistent perceived physical dysfunction during high level tasks, but remain capable of participating in organized team activities. However, the current study expands on this finding by demonstrating athletes with a history of knee injury as having lower PRO scores at discharge from current injury as well which suggests that clinicians should account for previous experiences when interpreting post-treatment assessment results as those experiences may be influencing the recovery process.

Conversely, history of injury did not seem to influence the ankle as greatly as it did for the knee. There were no statistical differences in PRO score or physical performance test result between athletes with and without a previous ankle injury. This could have occurred for multiple reasons. First, there was a larger difference in the between-group sample size for the subjects who did and did not sustain a previous ankle

injury (18 previous injuries vs. 6 without previous injury). It is possible the limited number of subjects without previous injury experience was not an appropriate representative sample for the history of injury comparison thus contributing to the lack of difference between the groups. Second, previous injury severity was not obtained so it is difficult to determine if the subjects who experienced a previous knee injury had more severe injury in the past compared to those subjects who experienced a previous ankle injury and therefore had lower perceived physical function to begin the season. The majority of the information that exists about ankle injuries has been directed towards individuals classified as having chronic ankle instability or those classified as “copers” – individuals who had a previous ankle sprain but have not had a secondary episode^{48,140,141,146,213,219-224}. In the current study, athletes were only screened for the occurrence of a previous ankle injury, not for the total number of previous incidents. However, the baseline FADI and FADI Sport median values reached the highest score of 104 and 32 respectively (this occurred for athletes with and without a previous ankle injury) which suggests the athletes were likely not perceiving ongoing deleterious effects from previous ankle injuries prior to the beginning of the season.

Return to pre-injured levels of activity is a common goal for clinicians and patients following the completion of rehabilitation for musculoskeletal injury, therefore; this study aimed to determine if athletes who sustain a musculoskeletal injury to the shoulder, elbow, knee, or ankle return to their individual level of physical function following rehabilitation. Considering the PRO results (patient factor) were the most affected, the study findings at this time suggest that the patient component within the Optimal Outcome Model⁶⁰ may be partially overlooked during the rehabilitation process.

This was demonstrated by the lack of difference between baseline and discharge assessments of physical performance testing (clinician factor) and that return to sport (external factor) occurred for the majority of athletes in the same season. Traditionally, physical impairments such as weakness and inflexibility are identified through standard clinical measures (manual muscle testing and goniometric measurements) and, following intervention, patients are considered to be successfully rehabilitated strictly on the improvement or resolution of the impairments. However, patients may not be concerned with obtaining a specific amount of range of motion or the ability to generate an acceptable amount of force on a muscle test but instead define rehabilitation as successful when their ability to perform their sport at levels prior to injury¹⁰⁸ has been restored. This discrepancy in the definition of successful rehabilitation between patients and clinicians has been noted in previous work where patients did not feel rehabilitation was successful although they had improvement or resolution of impairments as determined through isolated clinical measures^{109,110,225}. While the current study did not examine whether patients felt rehabilitation was successful prior to or after return to activity, this finding of the KOOS SX and KOOS PN scores being similar to baseline values and the KOOS SP, KOOS QL, and FADI scores being deficient when return to play was permitted could be a potential example where clinicians focused primarily on clinical factors as part of the rehabilitation process.

The results of this study demonstrate that the treating clinicians were obtaining acceptable treatment outcomes as all athletes who did not require surgery returned to activity in the same season following completion of treatment. However, the variation in self-reported physical function scores and lack of alteration in physical task performance

suggests that clinicians should potentially review current rehabilitation program design to assure all factors within the Optimal Outcome Model are equally addressed during supervised treatment. Although the non-surgical athletes returned to activity, clinicians should continue to monitor and possibly assess perceived ability to participate in sport and quality of life in athletes after discharge as it appears certain aspects of perceived physical function can continue to be below baseline values up to 6 months after discharge while other constructs can be restored to pre-season baseline values at time of discharge. It is possible that expert resources such as psychologists who are better equipped to manage psychological issues may need to be consulted to help overcome the lower levels of quality of life being reported by the athletes. Furthermore, part of the rationale for conducting this study was based on the premise that re-injury or injury exacerbation would occur if pre-injured values of subjective and objective physical function were not restored when athletes were discharged from formal care. It was interesting that neither re-injury nor exacerbation occurred during the active season when return to activity was permitted, yet a different phenomenon was identified where some athletes decided to not only discontinue participating in their sport but to leave the academic institution as well. While the limited sample size cannot allow definitive conclusions to be drawn, it is possible that different psychological assessments and relevant interventions may decrease the possibility of injured athletes electing to discontinue their athletic or academic careers following injury. Furthermore, future studies should examine if quality of life or other related constructs would improve at the discharge time period if clinicians were provided access to the scores throughout the treatment process.

Limitations

There are noted limitations with this study. First, the small sample size limits the value of the conclusions. However, this investigation was designed to serve as a feasibility study to determine if the extensive prospective design could be executed. Additionally, it is possible that there were athletes who sustained an injury during the study monitoring period but did not report the event to the sports medicine staff. Second, although defined by the research team, “injury” may be perceived differently by individual athletes based on previous experiences. It is possible both history of injury responses and current injury reporting were impacted by perceived definitions of the term. Third, it is possible different physical performance measures could yield different results. However, the dynamic tasks employed in this study were selected because they have literature support for their use, are applicable to the joints examined in this study, and were generalizable to multiple types of athletes. Finally, the blinding of the treating clinicians in some cases may have led to the decreased subjective results at the discharge time point and beyond. Patients have been reported to seek treatment for the inability to perform activities rather than for specific anatomical impairments or derangement²²⁶. In other words, a patient will often seek medical consultation and evaluation for the inability to run or throw a ball rather than specifically for meniscal pathology or rotator cuff tendinopathy. Although the clinicians had access to each subject’s pertinent information related to the sustained injury (i.e. subjective history, exam findings, etc.), withholding the treating clinicians from the specific items each injured subject perceived as being deficient at all stages of the study could have led to the alteration in PRO scores and would have skewed the research team’s ability to record the natural history of perceived and demonstrable physical function.

Conclusions

To the authors' knowledge, this is the first study to track both patient-reported and demonstrable physical function in collegiate athletes in a prospective, longitudinal manner. The study revealed that patient perception of symptoms and pain aligned with a blinded clinician making the decision to return an injured athlete to sport following rehabilitation, while the perceived ability to participate in sport and quality of life were diminished. Employing a prospective approach to establishing baseline physical function values for each individual athlete helped bolster the concept of identifying a return to pre-injured levels of activity. Additionally, accounting for a history of previous injury contributed to identifying variations in baseline values, the resultant outcome after injured occurred, and the outcome after return to activity was permitted. Both the prospective approach and history of injury appreciation directly affected the patient factor within the Optimum Outcome Model suggesting that clinicians should pay particular attention to individual patient concerns and previous experiences. Although subjective and objective function is near normal for ankle injuries at discharge, knee injuries require 1-6 months to fully recover after discharge, particularly those athletes with a previous injury history.

Table 5.1: Descriptive Statistics for Demographic Variables for Subjects who sustained a Knee Injury

	Overall (n=17)
Age (years)	
Mean (SD)	19 (1)
Range	17-21
Time Playing Sport (years)	
Mean (SD)	14 (3)
Range	7-16
Sex	
Male	12 (71%)
Female	5 (29%)
Height (centimeters)	
Mean (SD)	178 (10)
Range	163-198
Weight (kilograms)	
Mean (SD)	75 (11)
Range	55-95
BMI	
Mean (SD)	21 (3)
Range	16-29
Knee Injury Ever	
Yes	10 (59%)
No	7 (41%)
Days Missed for Injury	
Mean (SD)	12 (8)
Range	2-22

SD = standard deviation; BMI = Body Mass Index

Table 5.2. Knee Injury Subjective and Objective Results from Baseline to 6 Month Post return to Sport (N=17) reported as median (interquartile range)

	Baseline	Initial Injury	Discharge	1 Month Follow-up	3 Month Follow-up	6 Month Follow-up
KOOS SX	93 (82-100)	79 (64-86)*†	86 (75-93) †	93 (75-100)	96 (86-100)	93 (86-100)
KOOS PN	97 (89-100)	78 (67-86)* †	89 (83-97)	97 (86-100)	97 (89-100)	97 (92-100)
KOOS SP	90 (85-100)	63 (23-73)* †	75 (63-95) †	95 (80-100)	98 (85-100)	95 (75-100)
KOOS QL	100 (88-100)	66 (53-88)* †	75 (69-84)* †	94 (75-100)	94 (75-100)	94 (81-100)
SLH (cm)	180 (140-208)	---	164 (144-191) †	182 (167-207)	---	---
SEBT (%LL)	65% (61-69)	---	64% (61-68)	60% (58-61)	---	---

KOOS=Knee Injury and Osteoarthritis Outcome Score; SX=Symptom; PN=Pain; SP=Sport and Recreation Function; QL=Knee-Related Quality of Life; SLH=Single Leg Hop; SEBT=Star Excursion Balance Test (Anterior Reach only); cm=centimeters; %LL=percent leg length

*Score significantly decreased compared to baseline value $p \leq 0.01$

† Score beyond minimal detectable change

Note: the SLH and SEBT were not performed at initial injury evaluation; The SLH and SEBT values returned to baseline either at the discharge or 1 month follow-up time period. Therefore, no measures were obtained once baseline values were achieved.

Table 5.3. Knee Injury Subjective and Objective Results by History of Previous Knee Injury reported as median (interquartile range)

	Baseline	Initial Injury	Discharge	1 Month Follow-up	3 Month Follow-up	6 Month Follow-up
KOOS SX						
Previous Injury (n=10)	88 (75-96)	75† (64-82)	80† (64-89)	93 (75-93)	89 (71-95)	86 (70-93)
No Previous Injury (n=7)	100 (93-100)	79*† (46-96)	89† (75-100)	100 (86-100)	100 (100-100)	100 (96-100)
KOOS PN						
Previous Injury (n=10)	92 (83-97)	81*† (72-86)	89 (75-94)	89 (86-94)	89 (76-93)	89 (74-94)
No Previous Injury (n=7)	100 (100-100)	78*† (56-92)	97* (83-100)	100 (100-100)	100 (100-100)	100 (100-100)
KOOS SP						
Previous Injury (n=10)	85 (85-90)	65*† (20-75)	75 (45-75)	80 (80-80)	83 (70-90)	72 † (54-75)
No Previous Injury (n=7)	100 (100-100)	38*† (25-70)	95 (75-100)	100 (100-100)	100 (100-100)	100 (100-100)
KOOS QL						
Previous Injury (n=10)	88 (81-100)	66*† (50-81)	75*† (69-81)	75† (75-88)	72 † (56-81)	78 † (53-81)
No Previous Injury (n=7)	100 (100-100)	75*† (56-100)	78*† (69-100)	100 (100-100)	100 (100-100)	100 (100-100)
SLH (cm)						
Previous Injury (n=10)	176 (135-195)	---	161*† (129-188)	180 (145-182)	---	---
No Previous Injury (n=7)	193 (145-215)	---	178† (158-196)	203 (183-217)	---	---
SEBT (%LL)						
Previous Injury (n=10)	67% (61-69)	---	65% (60-68)	58% (58-59)	---	---
No Previous Injury (n=7)	64% (63-65)	---	64% (62-65)	61% (61-61)	---	---

KOOS=Knee Injury and Osteoarthritis Outcome Score; SX=Symptom; PN=Pain; SP=Sport and Recreation Function; QL=Knee-Related Quality of Life; SLH=Single Leg Hop; SEBT=Star Excursion Balance Test (Anterior Reach only); cm=centimeters; %LL=percent leg length

*Significantly decreased compared to baseline value $p \leq 0.05$

Bolded values for each time point indicate subjects with a previous knee injury had significantly lower scores compared to subjects without a previous knee injury

† Score beyond minimal detectable change

Note: the SLH and SEBT were not performed at initial injury evaluation; The SLH and SEBT values returned to baseline either at the discharge or 1 month follow-up time period. Therefore, no measures were obtained once baseline values were achieved.

Table 5.4. Descriptive Statistics for Demographic Variables for Subjects who sustained an Ankle Injury

	Overall (n=24)
Age (years)	
Mean (SD)	19 (1)
Range	17-21
Time Playing Sport (years)	
Mean (SD)	12 (5)
Range	2-18
Sex	
Male	12 (50%)
Female	12 (50%)
Height (centimeters)	
Mean (SD)	177 (11)
Range	158-196
Weight (kilograms)	
Mean (SD)	77 (16)
Range	59-135
BMI	
Mean (SD)	22 (5)
Range	17-38
Ankle Injury Ever	
Yes	18 (75%)
No	6 (25%)
Days Missed for Injury	
Mean (SD)	17 (20)
Range	2-95

SD = standard deviation; BMI = Body Mass Index

Table 5.5. Ankle Injury Subjective and Objective Results from Baseline to 6 Month Post return to Sport (N=24) reported as median (interquartile range)

	Baseline	Initial Injury	Discharge	1 Month Follow-up	3 Month Follow-up	6 Month Follow-up
FADI	104 (101-104)	55 (41-71)* †	98 (93-103)* †	104 (102-104)	104 (103-104)	104 (104-104)
FADI SP	32 (30-32)	6 (1-13)* †	29 (25-30)*	32 (29-32)	32 (30-32)	32 (31-32)
SLH (cm)	146 (118-185)	---	142 (133-173)	164 (147-171)	---	---
SEBT (%LL)	67% (61-70)	---	65% (61-73)	67% (66-69)	---	---

FADI=Foot and Ankle Disability Index; SP=Sport component of FADI; SLH=Single Leg Hop; SEBT=Star Excursion Balance Test (Anterior Reach only); cm=centimeters; %LL=percent leg length

*Score significantly decreased compared to baseline value $p \leq 0.01$

† Score beyond minimal detectable change

Note: the SLH and SEBT were not performed at initial injury evaluation; The SLH and SEBT values returned to baseline either at the discharge or 1 month follow-up time period. Therefore, no measures were obtained once baseline values were achieved.

Table 5.6. Ankle Injury Subjective and Objective Results by History of Previous Ankle Injury reported as median (interquartile range)

	Baseline	Initial Injury	Discharge	1 Month Follow-up	3 Month Follow-up	6 Month Follow-up
FADI						
Previous Injury (n=18)	104 (100-104)	53*† (40-74)	100* (94-103)	104 (101-104)	104 (103-104)	104 (104-104)
No Previous Injury (n=6)	104 (104-104)	57*† (46-63)	95 (93-103)	104 (104-104)	104 (104-104)	104 (104-104)
FADI SP						
Previous Injury (n=18)	32 (29-32)	8*† (1-14)	30* (26-30)	32 (29-32)	32 (30-32)	32 (29-32)
No Previous Injury (n=6)	32 (32-32)	5*† (0-9)	28 (22-30)	32 (30-32)	32 (32-32)	32 (32-32)
SLH (cm)						
Previous Injury (n=18)	142 (118-182)	---	142 (133-180)	148 (134-177)	---	---
No Previous Injury (n=6)	158 (125-185)	---	135 (132-164)	168 (164-171)	---	---
SEBT (%LL)						
Previous Injury (n=18)	67% (61-70)	---	68% (63-77)	69% (67-77)	---	---
No Previous Injury (n=6)	67% (61-68)	---	61%† (59-63)	66% (61-67)	---	---

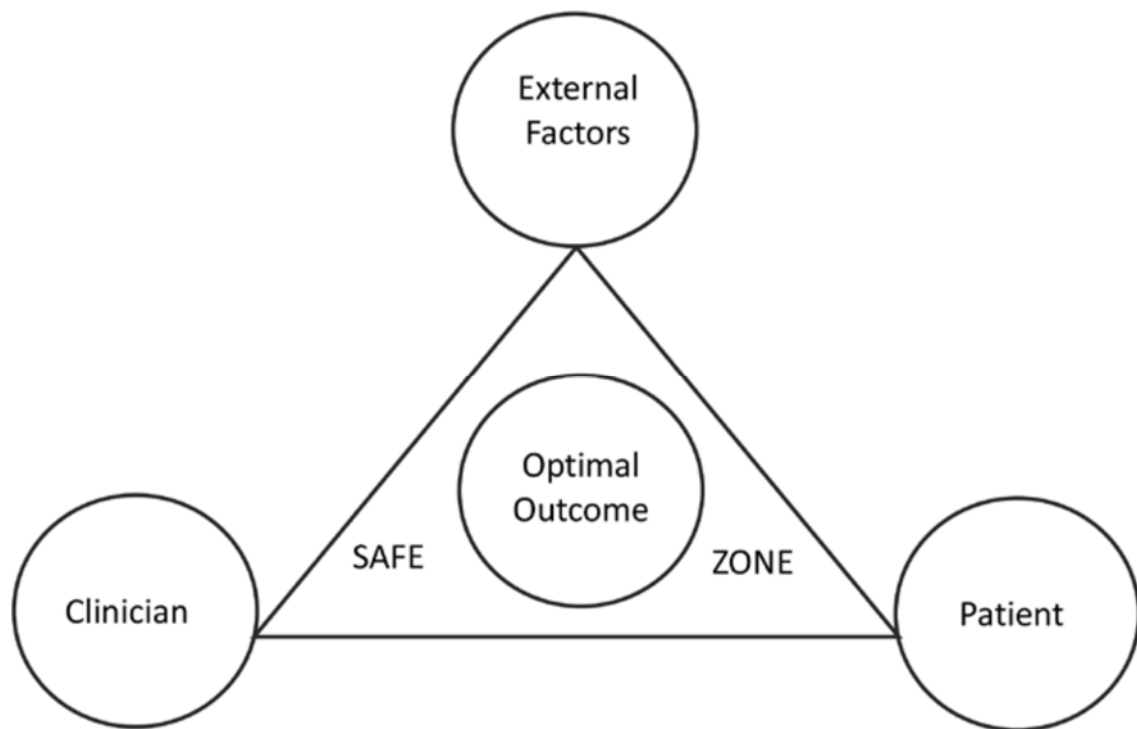
FADI=Foot and Ankle Disability Index; SP=Sport component of FADI; SLH=Single Leg Hop; SEBT=Star Excursion Balance Test (Anterior Reach only); cm=centimeters; %LL=percent leg length

* Significantly decreased compared to baseline value $p \leq 0.03$

† Score beyond minimal detectable change

Note: the SLH and SEBT were not performed at initial injury evaluation; The SLH and SEBT values returned to baseline either at the discharge or 1 month follow-up time period. Therefore, no measures were obtained once baseline values were achieved.

Figure 5.1. The Optimal Outcome Model



Chapter Six: Summary

The first purpose of this dissertation was to determine how collegiate athletes, with or without a history of injury, perceive their ability to physically perform athletic tasks prior to the beginning of a season. The second purpose was to assess the test/re-test reliability of a commonly utilized upper extremity specific physical performance test and to determine if the test could distinguish between individuals with and without shoulder symptoms. The third purpose of this dissertation was to obtain baseline values of pre-injured physical function and determine if athletes return to those baseline levels of perceived and demonstrable physical function following musculoskeletal injury.

Hypothesis and Findings Specific Aim 1

Specific Aim 1: Determine if self-perceived ability to physically function in athletes is impacted similarly in athletes with and without a history of injury. The primary outcome will be the amount of difference between the PRO scores between athletes with and without an injury history.

Hypothesis: Athletes with a history of injury will have a significantly lower level of perceived physical function compared to athletes without a history of injury prior to the beginning of a competitive sports season.

Finding: This hypothesis was accepted as athletes reporting a previous knee, shoulder, or elbow injury have perceived lower physical function prior to a competitive season although they were medically cleared to participate in sport.

Hypotheses and Findings Specific Aim 2

Specific Aim 2: To establish the reliability of traditional upper extremity strength testing and a physical performance measure for the upper extremity (CKCUEST) in persons with

and without shoulder symptoms as well as to determine if the testing maneuvers could discriminate between individuals with and without shoulder symptoms.

Hypotheses 1: The strength testing and the physical performance measure would have excellent test/re-test reliability for both testing groups.

Finding: This hypothesis was accepted showing that excellent test/re-test reliability existed for all tests (intraclass correlations $\geq .85$ for all tasks) in subjects with and without shoulder symptoms.

Hypothesis 2: Asymptomatic individuals will demonstrate better performance on the CKCUEST than symptomatic individuals.

Finding: The hypothesis that the CKCUEST could distinguish between individuals with and without shoulder symptoms was partially rejected as the evidence was trending towards supporting the hypothesis ($p=.064$) but was by definition ($p<.05$) not statistically different between the performances of the 2 subject groups.

Hypotheses and Findings Specific Aim 3

Specific Aim 3: Determine if athletes return to baseline values of physical function when return to activity is permitted. The primary outcome will be the amount of difference between the pre-season and discharge measurements. The secondary aim was to determine if injury history affects perceived and demonstrable physical function at the return to activity time period.

Hypothesis 1: Athletes that return to sport following an injury will not have a significantly lower level of physical function compared to their pre-season baseline level of physical function.

Finding: The primary hypothesis that collegiate athletes would not have significantly

different perceived and demonstrable physical function between baseline and discharge time points was partially confirmed as scores for 2 subscales of the KOOS (SX and PN) and both single leg hop and anterior reach of the SEBT physical performance task results were similar to baseline values at discharge. However, the KOOS SP, KOOS QL, FADI, and FADI Sport scores were significantly reduced at discharge compared to baseline values.

Hypothesis 2: Athletes with a history of injury will have significantly lower perceived and demonstrable physical function scores compared to athletes without a history of injury.

Finding: The secondary hypothesis was also partially confirmed as subjects with a previous knee injury had lower KOOS scores compared to subjects without a previous knee, yet there were no statistical differences in PRO score or physical performance test result between athletes with and without a previous ankle injury.

Synthesis and Application of Results

The first study of this dissertation was carried out to identify baseline self-reported physical function relative to the perceived state of the knee, shoulder, and elbow in a wide array of athletes before the commencement of injury exposure. It was determined that 1) overall, collegiate athletes report near perfect scores on selected KOOS subscales and the KJOC similar to values previously reported in the literature and 2) athletes reporting a previous knee, shoulder, or elbow injury have perceived lower physical function prior to a competitive season although they were medically cleared to participate in sport. These findings highlight the importance of comprehensively screening all athletes because traditional medical qualification does not necessarily

account for the individual athlete's perception of his or her ability to perform dynamic athletic maneuvers, whether basic (forward running or jumping) or complex (throwing, striking, or cutting), during sport activities. Therefore, employing a screening that involves both the traditional medical examination and the assessment of self-perceived physical function is recommended to provide a broader view of individual persons and factors which could have an adverse impact on physical performance and/or well-being.

Current reports have noted that the CKCUEST and traditional strength testing maneuvers have excellent test/re-test reliability in asymptomatic individuals. The second study of this dissertation attempted to expand on that knowledge by establishing if the CKCUEST and traditional strength testing maneuvers could be reliably employed in persons with and without shoulder symptoms and if the CKCUEST could distinguish between both groups. It was determined that the CKCUEST and traditional strength testing maneuvers have excellent test/re-test reliability for both persons with and without shoulder symptoms. No test could clearly distinguish between individuals with and without shoulder symptoms, however; the CKCUEST could have a role as a task to determine readiness to return to activity as it was trending towards being able to discriminate between known groups. However, it will be necessary for future work to examine other upper extremity physical performance measures in a similar fashion in order to determine if there is a standard test that has a better ability to discriminate between persons with and without active musculoskeletal symptoms.

Using the findings from the first and second study as a guide, the primary purpose of this dissertation was to assess perceived and demonstrable physical function in collegiate athletes in a longitudinal manner in order to trace the natural history of

physical function from a pre-injured time point to a post-injured time point. The dissertation was developed as a precursor to future testing of the Optimal Outcome Model which theorizes that it is the responsibility of the clinician to begin the rehabilitation process by putting the condition in context to the individual patient (via PROs) while adding in complementary pieces such as clinical factors (impairment measures of strength, range of motion, girth, physical performance testing, etc.) and external factors (returning the patient to pre-injured levels of activity) in order to create balance amongst the influential factors to achieve the best possible rehabilitation outcome. Overall, the results of the third study demonstrated that not all athletes perceive their physical function as restored to baseline levels when discharged from rehabilitation to return to sport. Additionally, previous injury history negatively affects perceived physical function at both baseline and post-rehabilitation time points for persons who previously sustained a knee injury but not individuals who previously sustained an ankle injury. The demonstrable physical function was restored no later than 1 month after return to activity was permitted and was not affected by a previous injury history.

There are 2 clinically relevant implications from the results of the third study. First, perceived and demonstrable physical function following rehabilitation for musculoskeletal injury in collegiate athletes appears to be affected up to 1 month after discharge. This finding is in line with a recent clinical opinion that athletes may be discharged from formal treatment but continue to be deficient in the ability to perform. The deficiencies may not necessarily be obvious limitations that prevent the athletes from participating in some level of organized team activities²⁰⁹. However, clinicians should utilize metrics such as PROs to gauge athlete perception in order to adjust activity levels

as needed to enhance recovery.

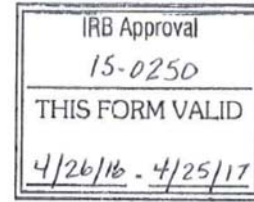
Second, the results derived from assessing perception of physical function in athletes may be dependent on the metric or questionnaire being utilized for the assessment. The results from the third study suggest that psychological constructs such as quality of life or general health-based question may be affected for at least 6 months after return to activity has been permitted while anatomically-based constructs such as pain, symptoms, sport activity performance, etc. recover within 1 month from being discharged from rehabilitation. This was evident in persons who had a previous history of knee injury. When compared to baseline, the KOOS QL subscale for persons who sustained a previous knee injury was decreased beyond minimal detectable change at all time points while the other KOOS subscales were within baseline values at the 1 month follow-up time period. The FADI and FADI Sport, which contain mostly activity-specific questions and no questions focused on quality of life, indicated that athletes returned to baseline levels of perceived physical function by the 1 month follow-up time period. This suggests that clinicians should not discount patient-specific factors as they can influence individual patient results and that careful PRO selection is necessary in order for clinicians to truly assess all aspects of perceived physical function.

In conclusion, the obtainment of clinical benchmarks to determine medical qualification for sport activity does not necessarily parallel patient-perceived ability to function. However, exclusively utilizing only subjective assessments of physical function or objective assessments to make clinical decisions would be incomplete. In order to avoid placing too much emphasis on either subjective or objective assessments of physical function as the sole means of determining readiness to return to sport, a

comprehensive approach which considers the patient, clinician, and external factors within the rehabilitation process could be utilized to increase the occurrence of positive treatment outcomes i.e. return to pre-injured levels of activity. Future studies should consider replicating these methods to determine if similar phenomena occur.

Additionally, future studies should attempt to test the practical application of the Optimal Outcome Model in clinical practice to determine if outcomes can improve when all model components are accounted for.

Appendix A. Consent Form



Consent to Participate in a Research Study

Prospective Assessment of Return to Pre-Injured Levels of Activity

WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?

You are being invited to take part in a research study which will look at the effect of injury on your ability to perform athletic tasks. You are being invited to take part in this research study because you are a collegiate athlete between the ages of 18-35 years old. If you volunteer to take part in this study, you will be one of about 3000 people to do so.

WHO IS DOING THE STUDY?

The person in charge of this study is Tim Uhl, PhD, ATC, PT, FNATA (Principal Investigator, PI) of University of Kentucky, Department of Rehabilitation Science. There may be other people on the research team assisting at different times during the study.

WHAT IS THE PURPOSE OF THIS STUDY?

By doing this study, we hope to learn if your ability to use your arms and legs during pre-season physicals is the same after injury occurs. We also hope to learn how often a second injury occurs after you have been allowed to return to sport following an initial injury. This will help medical professionals decide how long to treat and monitor a college athlete after injury occurs.

ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

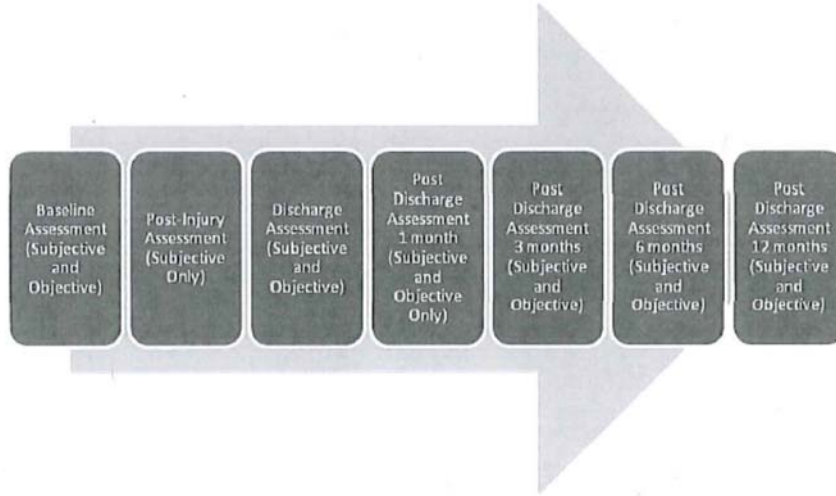
If you do not feel comfortable participating in a research study, you should not do so. You should not volunteer for this study if you are under the age of 18 years old or over the age of 35 or are currently not medically cleared to participate in strenuous activity such as competitive sports due to a current disease, illness, or other medical condition.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

The research procedures will be conducted at your school however the schools participating in this study include Asbury University, Transylvania University, and Eastern Kentucky University. In the event you experience an injury to the shoulder, elbow, knee, or ankle during the next year, the total amount of time you will be asked to volunteer for this study is 150 minutes over the next year. In the event you do not sustain an injury to the shoulder, elbow, knee, or ankle over the next year, the total amount of time you will be asked to volunteer for this study is 30 minutes over the next year.

WHAT WILL YOU BE ASKED TO DO?

You will be initially tested during pre-season physical examinations with the testing taking approximately 20 minutes. During this testing you will be asked to complete a packet of questionnaires which should take no longer than 5 minutes. You will also be asked to perform physical tests. One test is called the closed kinetic chain upper extremity stability test. You will be asked to move your hands side-to-side performing as many hand touches as you can while maintaining proper push-up form. This test will be performed 2 times with each trial lasting 15 seconds. The second test is called a single leg hop for distance. You will be asked to stand on 1 leg and jump as far forward as you can. This test will be performed 3 times on each leg. The third test will test is known as dynamic balance testing which will help show how well you balance during movement. For the dynamic balance testing, you will be asked to stand barefoot on one leg at the beginning of three different tape measures taped down on the floor. You will reach as far as you can with your other leg along the tape measures in each of the three different directions. For each reach, you will be asked to reach with your foot, touch down gently with your toes, and return to your starting position. You will reach 3 times on each leg in each of the three directions, for a total of 6 times in each of the three directions. You will then be monitored for the occurrence of an injury during your competitive season. If you sustain an injury about the shoulder, elbow, knee, or ankle, you will be asked to complete a brief questionnaire on the day you report your injury to the athletic training staff at your school. This questionnaire will be sent to you electronically so the athletic training staff or coaches cannot see your responses. The questionnaire should take no longer than 3 minutes to complete. You will be asked to repeat the same testing procedure as conducted in pre-season physicals on the day the athletic training staff releases you to full sport participation. If your results are equal to the results from your pre-season testing, then you will be asked to complete a questionnaire at 1 month, 3 months, 6 months, and 12 months after return to activity. You will be monitored for an additional injury throughout the academic year until you report for the following year's pre-season physical examination. If your results are not equal to the results from your pre-season testing, you will be asked to repeat the same procedures at 1 month, 3 months, 6 months, and 12 months after return to activity until your results are equal to the pre-season results.





WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

There are minimal risks that could occur by taking part in this study. Muscle tiredness (fatigue) and muscle soreness may be possible following the physical testing. The fatigue and soreness (if any) would be expected to be no greater than that which occurs during a traditional exercise routine and could last up to 48-72 hours. If you currently have pain at or about the shoulder, elbow, knee, or ankle and/or a known injury at or about the shoulder, elbow, knee, or ankle, the pain or injury could worsen during or following the testing. You may also become bored or tired from completing the questionnaires. It is possible that you could sustain an injury in the act of performing the physical performance tasks but the risk is not anticipated to be any greater than the risk of injury that exists with exercise activities similar to push-ups and jumping. There is an extremely small risk that you might fall during the balance testing. The investigators will instruct you in how to appropriately perform each task and allow you to practice each task until you feel comfortable performing them. In addition to the risks listed above, you may experience a previously unknown risk or side effect.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?

You will not get any personal benefit from taking part in this study. Your willingness to take part, however, may, in the future, help medical professionals improve treatment programs for athletic injury and understand the effect of an initial injury on future injury occurrence. We will provide you with a summary of your individual results after the study has been completed.

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 benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. If you are a volunteer who sustains an injury during the season and decide not to take part in this study, your decision will have no effect on the quality of medical care you receive (assuming your injury would require medical treatment).

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

If you do not want to be in the study, there are no other choices except not to take part in the study.

WHAT WILL IT COST YOU TO PARTICIPATE?

There are no financial costs associated with taking part in the study. The only cost foreseen with participating in this study is time with a minimum of 30 minutes and a maximum of 150 minutes being required to participate.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?

We will make every effort to keep confidential all research records that identify you to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may publish the results of this study; however, 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. Your testing results will be entered into an electronic database



located on a secure network at the University of Kentucky. The computer database program, REDCap, allows for us to access your data using a randomized code that cannot be connected to your personal information. To limit the number of individuals who could view the study information, only the principle investigator (Tim Uhl) and the co-investigators (Aaron Sciascia, Autumn Whitson, and Jordan Light) will have access to the electronic database.

Please be aware, while we make every effort to safeguard your data once received on our servers via REDCap, given the nature of online surveys, as with anything involving the Internet, we can never guarantee the confidentiality of the data while still en route to us. Officials from the University of Kentucky, Asbury University, Transylvania University, or Eastern Kentucky University may look at or copy pertinent portions of records that may identify you.

CAN YOUR TAKING PART IN THE STUDY END EARLY?

If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study. The individuals conducting the study may need to withdraw you from the study if any of the following conditions occur: an injury occurs as a result of testing, pain advances to where surgery may be needed, you have or have developed a current illness that prevents further performance of exercise, or general or specific changes in your condition medically disqualify you from participating.

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

You may 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 also discuss with the investigator before you agree to participate in another research study while you are enrolled 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 done during the study, you should call Tim Uhl at 859-218-0858 or Aaron Sciascia at 859-258-8506 immediately. Tim Uhl or Aaron Sciascia will determine what type of treatment or referral, if any, that is best for you at that time. It is important for you to understand that the University of Kentucky will not 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. That cost will be your responsibility. Also, the Lexington Clinic will not pay for any wages you may lose if you are harmed by this study.

Usually, medical costs that result from research-related harm cannot be included as regular medical costs. The University of Kentucky is not allowed to bill your insurance company, Medicare, or Medicaid for these costs without first getting permission. You should ask your insurer if you have any questions about your insurer's willingness to pay under these circumstances. Therefore, the costs related to your care and treatment because of something that is done during the study will be your responsibility. These costs 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). A co-payment/deductible from you may be required 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 substantial.

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 YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Tim Uhl at 859-323-1100 x 80858. If you have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity between the business hours of 8am and 5pm EST, Mon-Fri at the University of Kentucky at 859-257-9428 or toll free at 1-866-400-9428. We will give you a signed copy of this consent form to take with you.

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

If the researcher learns of new information in regards to this study, and it might change your willingness to stay in this study, the information will be provided to you. You may be asked to sign a new informed consent form if the information is provided to you after you have joined the study.

WHAT ELSE DO YOU NEED TO KNOW?

There is a possibility that the data collected from you may be shared with other investigators in the future. If that is the case the data will not contain information that can identify you unless you give your consent or the UK Institutional Review Board (IRB) approves the research. The IRB is a committee that reviews ethical issues, according to federal, state and local regulations on research with human subjects, to make sure the study complies with these before approval of a research study is issued.

Signature of person agreeing to take part in the study

Date

Printed name of person agreeing to take part in the study

Name of [authorized] person obtaining informed consent

Date

Signature of Principal Investigator or Sub/Co-Investigator

Appendix B. Demographic Form and Patient Reported Outcome Measures

Name: _____ Email: _____

Cell Phone (to receive text messages): _____

Age (in years): _____ Gender (check one): Male Female

Dominant Arm (check one): Left Right

Race (check one): American Indian/Alaskan Native Asian Black/African American Hispanic/Latino
 Native Hawaiian/Pacific Islander White/Caucasian Other/Unknown

School (check one): Transylvania University Asbury University Eastern Kentucky University

Sport: _____ How many years have you played this sport?: _____

Current academic year in school (check one): Freshman Sophomore Junior Senior

Shoulder	Right		Left	
	Yes	No	Yes	No
Have you had a shoulder injury in the last 6 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had shoulder surgery in the last 6 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had a shoulder injury in the last 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had shoulder surgery in the last 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you ever had a shoulder injury	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Elbow				
Have you had an elbow injury in the last 6 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had elbow surgery in the last 6 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had an elbow injury in the last 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had elbow surgery in the last 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you ever had an elbow injury	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Knee				
Have you had a knee injury in the last 6 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had knee surgery in the last 6 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had a knee injury in the last 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had knee surgery in the last 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you ever had a knee injury	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ankle				
Have you had an ankle injury in the last 6 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had ankle surgery in the last 6 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had an ankle injury in the last 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you had ankle surgery in the last 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have you ever had an ankle injury	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

KJOC Instructions to athletes:

The following questions concern your physical functioning during game and practice conditions. Unless otherwise specified, all questions relate to your **Shoulder and Elbow**. Please answer with an “X” along the horizontal line that corresponds to your current level.

1. How difficult is it for you to get loose or warm prior to competition or practice?



2a. How much pain do you experience in your **shoulder**?



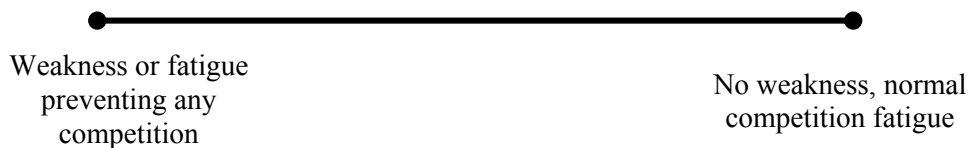
2b. How much pain do you experience in your **elbow**?



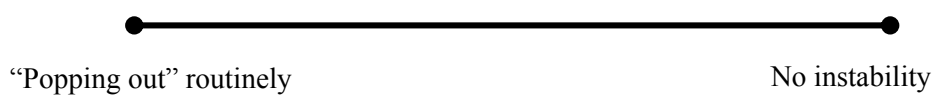
3a. How much weakness and/or fatigue (i.e. loss of strength) do you experience in your **shoulder**?



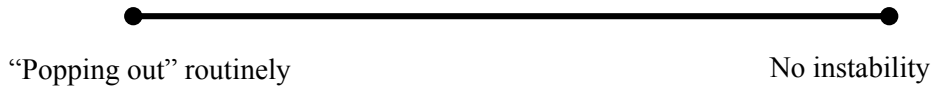
3b. How much weakness and/or fatigue (i.e. loss of strength) do you experience in your **elbow**?



4a. How unstable does your **shoulder** feel during competition?



4b. How unstable does your elbow feel during competition?



5. How much have arm problems affected your relationship with your coaches, management, and agents?



6. How much have you had to change your throwing motion, serve, stroke, etc. due to your arm?



7. How much has your velocity and/or power suffered due to your arm?



8. What limitation do you have in endurance in competition due to your arm?



9. How much has your control (of pitches, serves, strokes, etc.) suffered due to your arm?



Unpredictable control on
all pitches, serves, strokes,
etc.

No loss of control

10. How much do you feel your arm affects your current level of competition in your sport (i.e. is your arm holding you back from being at your full potential)?



Cannot compete, had to
switch sports

Desired level of competition

KOOS Knee Survey

This survey asks for your view about your knee. Please answer every question with one (1) response that most closely describes your condition within the past week.

Symptoms

	Never	Rarely	Sometimes	Often	Always
S1 Do you have swelling in your knee?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S2 Do you feel grinding or hear clicking or any other type of noise when your knee moves?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S3 Does your knee catch or hang up when moving?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Always	Often	Sometimes	Rarely	Never
S4 Can you straighten your knee fully?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S5 Can you bend your knee fully?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	None	Mild	Moderate	Severe	Extreme
S6 How severe is your knee joint stiffness after first waking in the morning?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S7 How severe is your knee joint stiffness after sitting, lying, or resting later in the day?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Pain

	Never	Monthly	Weekly	Daily	Always
P1 How often do you experience knee pain?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	None	Mild	Moderate	Severe	Extreme
P2 Twisting/pivoting on your knee	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
P3 Straightening knee fully	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
P4 Bending knee fully	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
P5 Walking on flat surface	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
P6 Going up or down stairs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
P7 At night while in bed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
P8 Sitting or lying	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
P9 Standing upright	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Function, sports, and recreation

Please answer every question with one (1) response that most closely describes how much difficulty you had during the following activities within the past week.

		None	Mild	Moderate	Severe	Extreme
SP1	Squatting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SP2	Running	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SP3	Jumping	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SP4	Twisting/pivoting on your injured knee	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SP5	Kneeling	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Quality of Life

		Never	Monthly	Weekly	Daily	Constantly
Q1	How often are you aware of your knee problem?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

		None	Mildly	Moderately	Severely	Extremely
Q2	Have you modified your life style to avoid potentially damaging activities to your knee?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Q3	How much are you troubled with lack of confidence in your knee?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

		None	Mild	Moderate	Severe	Extreme
Q4	In general, how much difficulty do you have with your knee?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Foot and Ankle Disability Index

Please answer every question with one (1) response that most closely describes your condition within the past week.

Activities: Check only 1 response for each item

	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Standing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking on even ground	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking on even ground w/o shoes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking up hills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking down hills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Going up stairs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Going down stairs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking on uneven ground	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Stepping up and down curves	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Squatting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sleeping	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Coming up to your toes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking initially	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking 5 minutes or less	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking about 10 minutes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking 15 minutes or more	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Home responsibilities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Activities of daily living	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Personal care	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Light to moderate work (standing, walking)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Heavy work (push/pulling, climbing, carrying)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Recreational activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Pain: Check only 1 response for each item

	No pain	Mild	Moderate	Severe	Unbearable
General pain level	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pain at rest	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pain with normal activity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pain first thing in morning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Sports Activities: Check only 1 response for each item

	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Running	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Jumping	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Landing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Squatting and stopping quickly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cutting, lateral movements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Low-impact activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ability to perform activity with your normal technique	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ability to participate in your desired sport as long as you would like	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Appendix C. Physical Performance Measure Follow-up Form

ID: _____ Name: _____ Date: _____
 Session: Preseason Discharge 1 Month 3 Month 6 Month
 Date of Injury: _____ Injury: Ankle Elbow Knee Shoulder
 Body Weight (BW): _____ lbs. Leg Length Right: _____ cm Leg Length Left: _____ cm

Test	Score
CKCUEST	
CKCUEST Trial 1	
CKCUEST Trial 2	
Single Leg Hop Right	
Single Leg Hop Right Trial 1	
Single Leg Hop Right Trial 2	
Single Leg Hop Right Trial 3	
Single Leg Hop Left	
Single Leg Hop Left Trial 1	
Single Leg Hop Left Trial 2	
Single Leg Hop Left Trial 3	
SEBT Ant Right	
SEBT Right Ant Trial 1	
SEBT Right Ant Trial 2	
SEBT Right Ant Trial 3	
SEBT Ant Left	
SEBT Left Ant Trial 1	
SEBT Left Ant Trial 2	
SEBT Left Ant Trial 3	

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VITA

Aaron D. Sciascia, MS, LAT, ATC, PES

Education

Graduate Certificate, Clinical and Translation Science, University of Kentucky, Lexington, KY
(August 2014)

Master of Science in Kinesiology, Specialization in Athletic Training, University of Kentucky, Lexington, KY
(May 2002)

Bachelor of Science in Athletic Training, University of Delaware, Newark, DE (May 2000)

Work Experience

(Aug 2016 – present) **Assistant Professor**, Eastern Kentucky University, Richmond, KY

(Feb 2016 – Aug 2016) **Sports Medicine Supervisor**, Lexington Clinic Orthopedics-Sports Medicine, Lexington, KY

(May 2009 – Feb 2016) **Shoulder Center Coordinator**, Shoulder Center of Kentucky, Lexington, KY

(March 2003 – Feb 2016) **Program Coordinator**, Lexington Clinic Sports Medicine Center, Lexington, KY

(Jan 2005 – May 2011) **Adjunct Professor**, Eastern Kentucky University, Richmond, KY

(Aug 2005 – May 2006) **Senior Thesis Mentor**, Eastern Kentucky University, Richmond, KY

(Aug 2002 – Feb 2003) **Assistant Athletic Trainer**, Cumberland College, Williamsburg, KY

(April 2001 – May 2002) **Instructor - Wellness: A Way of Life**, Centre College, Danville, KY

(Aug 2000 – May 2002) **Graduate Assistant Athletic Trainer**, University of Kentucky, Lexington, KY

(Jan 1998 – May 2000) **Athletic Training Student**, University of Delaware, Newark, DE

(May 1999 – July 1999) **Internship: Athletic Training Student**, Tampa Bay Mutiny, Tampa, FL

Professional Development

Publications

(In Review) **Publication:** W. Ben Kibler, Aaron Sciascia – **Management of the Scapula in Glenohumeral Instability** in Kibler WB, Sciascia AD (eds) Disorders of the Scapula and Their Role in Shoulder Injury – A Clinical Guide to Evaluation and Management Springer

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- (May 2015) **Publication:** Aaron Sciascia – **What are the Most Important Aspects of Patient Education and Home Exercise Programs for Improving Shoulder Function?** in Bliven K (ed) Quick Questions in the Shoulder: Expert Advice in Sports Medicine Thorofare: Slack pgs. 39-44, 2015
- (May 2015) **Publication:** Aaron Sciascia – **What are the Best Clinical Tests for Determining if a Patient has Scapular Dyskinesis and to Determine if it is Contributing to Their Shoulder Pain and Dysfunction?** in Bliven K (ed) Quick Questions in the Shoulder: Expert Advice in Sports Medicine Thorofare: Slack pgs. 159-164, 2015
- (December 2014) **Publication:** Stephanie Moore-Reed, W. Ben Kibler, Aaron D. Sciascia, Tim Uhl – **Preliminary Development of a Clinical Predication Rule for Treatment of Patients with Suspected SLAP Tears**, *Arthroscopy* 30(12): 1540-1549, 2014 doi: 10.1016/j.arthro.2014.06.015
- (October 2014) **Publication:** Tracy Spigelman, Aaron Sciascia, Tim Uhl – **Return to Swimming Protocol for Competitive Swimmers: A Post-Operative Case Study and Fundamentals**, *International Journal of Sports Physical Therapy* 9(5): 712, 2014
- (September 2014) **Publication:** Aaron Sciascia – **Rehabilitation for the Tennis Athlete**, *Aspetar Sports Medicine Journal* 3(4): pgs. 558-563, 2014
- (July 2014) **Publication:** Aaron Sciascia, W. Ben Kibler – **Nonoperative Shoulder Rehabilitation Using the Kinetic Chain** in Liebensohn C (ed) Functional Training Handbook Philadelphia: Wolters Kluwer pgs. 369-379, 2014
- (February 2014) **Publication:** W. Ben Kibler, John E. Kuhn, Aaron Sciascia, Tim Uhl – **The Overhead Athlete** in Milano G & Grasso A (eds) Shoulder Arthroscopy Principles and Practice London: Springer pgs. 229-247, 2014
- (January 2014) **Publication:** W. Ben Kibler, Aaron Sciascia, Trevor Wilkes – **Disorders of the Scapula: Winging and Snapping** in Iannotti JP, Miniaci A, Williams GR, and Zuckerman JD (eds) Disorders of the Shoulder: Diagnosis and Management 3rd Edition Volume 1: Shoulder Reconstruction Baltimore: Lippincott Williams & Wilkins pgs. 581-606, 2014
- (January 2014) **Publication:** W. Ben Kibler, Aaron Sciascia, Tim Uhl – **Medial Scapular Muscle Detachment: Clinical Presentation and Surgical Treatment**, *Journal of Shoulder and Elbow Surgery* 23(1): 58-67, 2014 doi: <http://dx.doi.org/10.1016/j.jse.2013.05.008>
- (September 2013) **Publication:** W. Ben Kibler, Trevor Wilkes, Aaron Sciascia – **Mechanics and Pathomechanics in Overhead Athletes**, *Clinics in Sports Medicine* 32(4): 637-

651, 2013 doi: <http://dx.doi.org/10.1016/j.csm.2013.07.003>

- (August 2013) **Publication:** W. Ben Kibler, Aaron Sciascia, John McMullen, Tim Uhl – **Rehabilitation of the Athlete’s Shoulder** in Cole B & Sekiya (eds) Surgical Techniques of the Shoulder, Elbow, and Knee in Sports Medicine 2nd Edition Elsevier, Philadelphia pgs. 13-21, 2013
- (July 2013) **Publication:** Cale Jacobs, Christian Christensen, Peter Hester, David Burandt, Aaron Sciascia – **Errors in Visual Estimation of Flexion Contractures during TKA**, *World Journal of Orthopedics* 4(3): 120-123, 2013 doi: 10.5312/wjo.v4.i3.120
- (May 2013) **Publication:** Aaron Sciascia – **A Basic Construct for Improving Outcomes in Rehabilitation**, *International Journal of Athletic Therapy and Training* 18(3):14-19, 2013
- (April 2013) **Publication:** W. Ben Kibler, Paula Ludewig, Phil McClure, Lori Michener, Klaus Bak, Aaron Sciascia – **Clinical Implications of Scapular Dyskinesia in Shoulder Injury: The 2013 Consensus Statement from the Scapula Summit**, *British Journal of Sports Medicine*, 47: 877-885, 2013 (published online first April 18, 2013 doi:10.1136/bjsports-2013-092425)
- (April 2013) **Publication:** W. Ben Kibler, Aaron Sciascia – **Introduction to the Second International Conference on Scapular Dyskinesia in Shoulder Injury – the “Scapular Summit” Report of 2013**, *British Journal of Sports Medicine*, 47: 874, 2013 (published online first April 18, 2013 doi:10.1136/bjsports-2013-092424)
- (March 2013) **Publication:** Aaron Sciascia, Daun Karolich – **A Comprehensive Approach for Non-Operative Treatment of the Rotator Cuff**, *Current Physical Medicine and Rehabilitation Reports* 1(1): 29-37, 2013
- (January 2013) **Publication:** W. Ben Kibler, Jed Kuhn, Kevin Wilk, Aaron Sciascia, Stephanie Moore, Kevin Laudner, Todd Ellenbecker, Chuck Thigpen, Tim Uhl – **The Disabled Throwing Shoulder Spectrum of Pathology: 10 Year Update**, *Arthroscopy* 29(1): 141-161, 2013
- (August 2012) **Publication:** Aaron Sciascia, Tim Uhl, Nina Kuschinsky, Arthur Nitz, Scott Mair – **Muscle Activity Comparison of Four Common Shoulder Exercises in Unstable and Stable Shoulders**, *Rehabilitation Research and Practice* ID:783824 Pgs. 1-11, 2012
- (July 2012) **Publication:** Aaron Sciascia, Tracy Spigelman, W. Ben Kibler, Tim Uhl – **The Frequency of Utilization of Clinical Shoulder Exam Tests by Experienced Shoulder Surgeons**, *Journal of Athletic Training* 47(4): 457-466, 2012
- (June 2012) **Publication:** W. Ben Kibler, Aaron Sciascia, Stephanie Moore – **Effect of Acute Exposure to Throwing and of Pitching Role on Short Term Shoulder Range of Motion**, *Clinical Orthopaedics and Related Research* 470:1545-1551, 2012
- (June 2012) **Publication:** W. Ben Kibler, Aaron Sciascia, Trevor Wilkes – **Scapular Dyskinesia and its Relation to Shoulder Injury**, *Journal of the American Academy of Orthopaedic Surgeons* 20(6): 364-372, 2012
- (May 2012) **Publication:** Aaron Sciascia, Robin Cromwell – **Kinetic Chain Rehabilitation:**

A Theoretical Framework, *Rehabilitation Research and Practice* ID: 853037
pgs. 1-8, 2012

- (March 2012) **Publication:** Aaron Sciascia, Charles Thigpen, Surena Namdari, Keith Baldwin– **Kinetic Chain Abnormalities in the Athletic Shoulder**, *Sports Medicine and Arthroscopy Review* 20(1): 16-21, 2012
- (March 2012) **Publication:** W. Ben Kibler, Aaron Sciascia, Stephen J Thomas – **Glenohumeral Internal Rotation Deficit: Pathogenesis and Response to Acute Throwing**, *Sports Medicine and Arthroscopy Review* 20(1): 34-38, 2012
- (January 2012) **Publication:** W. Ben Kibler, Aaron Sciascia – **Non-operative Management and Scapular Dyskinesia**, in Provencher M, Romeo A (eds) Shoulder Instability: A Comprehensive Approach, Elsevier, Philadelphia, pgs. 369-378, 2012
- (December 2011) **Publication:** W. Ben Kibler, Aaron Sciascia – **Scapular Dyskinesia in Shoulder Injury**, *Sports Medicine Update* 4(4): 3-6, 2011
- (November 2011) **Publication:** W. Ben Kibler, Aaron Sciascia – **Pitfalls in the Treatment of Shoulder Impingement**, in Kibler, WB (ed) Pitfalls in the Treatment of Common Shoulder Problems Monograph Series v46, American Academy of Orthopaedic Surgeons, Rosemont, 2011
- (November 2011) **Publication:** Cale Jacobs, Aaron Sciascia – **Factors that influence the efficacy of stretching programs for patients with hypomobility**, *Sports Health* 3(6): 520-523, 2011
- (October 2011) **Publication:** W. Ben Kibler, Aaron Sciascia – **Clinical Pearls: Scapular Evaluation**, Sports Medicine Research Blog October 2011
- (March 2011) **Publication:** W. Ben Kibler, Aaron Sciascia, John McMullen – **Scapular Dyskinesia** in Brotzman SB & Manske RC (eds) Clinical Orthopaedic Rehabilitation 3rd edition Elsevier, Philadelphia, pgs. 128-129, 195-198, 2011
- (July 2010) **Publication:** W. Ben Kibler, Aaron Sciascia, David Dome – **AC Joint Injuries**, *ISAKOS Newsletter* 14(2): 28-30, Summer 2010
- (May 2010) **Publication:** W. Ben Kibler, Aaron Sciascia – **Current Concepts: Scapular Dyskinesia**, *British Journal of Sports Medicine* 44(5):300-305, 2010.
- (December 2009) **Publication:** W. Ben Kibler, Aaron Sciascia, Todd Ellenbecker – **Musculoskeletal Aspects of Recovery for Tennis** in Kovacs MS; Ellenbecker TS; Kibler WB (eds) *Tennis Recovery: A Comprehensive Review of the Research*, pgs. 129-167 United States Tennis Association, White Plains, 2009.
- (November 2009) **Publication:** **Scapula Summit Consensus Statements** in Kibler WB, Ludewig PM, McClure PW, Uhl TL, Sciascia AD (eds) *Journal of Orthopaedic and Sports Physical Therapy*, 39(11): A1-A13, 2009.
- (September 2009) **Publication:** W. Ben Kibler, Aaron Sciascia, David Dome, Peter Hester, Cale Jacobs – **Clinical Utility of New and Traditional Exam Tests for Biceps and Superior Glenoid Labral Injuries**, *American Journal of Sports Medicine* 37(9): 1840-1847, 2009
- (March 2009) **Publication:** W. Ben Kibler, Aaron Sciascia – **Youth Throwing Injuries**, in

- Kibler, WB (ed) Orthopedic Knowledge Update: Sports Medicine 4, AAOS, Rosemont, pgs. 425-434, 2009.
- (March 2009) **Publication:** W. Ben Kibler, Aaron Sciascia, Brian Wolf, Bryan Warne, Jed Kuhn – **Nonacute Shoulder Injuries**, in Kibler, WB (ed) Orthopedic Knowledge Update: Sports Medicine 4 AAOS, Rosemont, pgs. 19-40, 2009
- (December 2008) **Publication:** W. Ben Kibler, Aaron Sciascia – **Rehabilitation of the Athlete’s Shoulder**, *Clinics in Sports Medicine* 27(4): 821-831, 2008.
- (September 2008) **Publication:** W. Ben Kibler, Aaron Sciascia, Tim Uhl, Nishin Tambay, Thomas Cunningham – **Electromyographic Analysis of Specific Exercises for Scapular Control in Early Phases of Shoulder Rehabilitation**, *American Journal of Sports Medicine* 36(9): 1789-1798, 2008.
- (June 2008) **Publication:** Andrea De Vita, W. Ben Kibler, Nicole Pouliart, Aaron Sciascia – **Scapulothoracic Joint**, in G. DiGiacomo, N. Pouliart, A. Constantini, A. De Vita. Atlas of Functional Shoulder Anatomy, pgs. 2-26, Springer, Milan, 2008.
- (April 2008) **Publication:** W. Ben Kibler, Aaron Sciascia – **What went wrong and what to do about it: Pitfalls in Treatment of Shoulder Impingement** in PJ Duwelius and FM Azar (eds) Instructional Course Lectures Volume 57 AAOS, Rosemont pgs. 103-112, 2008
- (September 2007) **Publication:** Aaron Sciascia, W. Ben Kibler - **Physically Speaking: Ace Your Game**, WTA Sport Sciences and Medicine Pro U Athlete Assistance, 2007
- (June 2007) **Publication:** Priscilla Dwelly, Brady Tripp, Aaron Sciascia – **Effect of Humeral Abduction Angle on a Clinical Measure of Glenohumeral Internal Rotation Deficit in Throwing Athletes**, *Journal of Athletic Training* 42(2): S21, 2007
- (December 2006) **Publication:** W. Ben Kibler, Aaron Sciascia – **The Shoulder in Tennis** *Journal of Sports Orthopaedics and Traumatology* 22(4): 223-230, 2006
- (December 2006) **Publication:** Aaron Sciascia – **Prevention of Injury in Tennis** *Medicine and Science in Tennis* 11(3): 13, 2006
- (November 2006) **Publication:** Aaron Sciascia, W. Ben Kibler – **The Pediatric Throwing Athlete: What is the Real Problem?** *Clinical Journal of Sports Medicine* 16(6): 471-477, 2006
- (October 2006) **Publication:** W. Ben Kibler, Aaron Sciascia, David Dome - **Evaluation of Apparent and Absolute Rotator Cuff Weakness in Shoulder Injury by the Scapular Retraction Test**, *American Journal of Sports Medicine* 34(10): 1643-1647, 2006
- (August 2006) **Contributor:** W. Ben Kibler, George Murrell – **Shoulder Pain**, in Brukner, P., Khan, K. (ed) Clinical Sports Medicine 3rd edition, McGraw Hill, Australia pgs. 243-288, 2006
- (August 2006) **Publication:** Aaron Sciascia, W. Ben Kibler – **Conducting the “Non-Shoulder” Shoulder Examination**, *The Journal of Musculoskeletal Medicine* 23(8): 582-598, 2006
- (March 2006) **Publication:** W. Ben Kibler, Joel Press, Aaron Sciascia - **The Role of Core**

Stability in Athletic Function, *Sports Medicine* 36(3): 189-198, 2006

- (October 2004) **Publication:** W. Ben Kibler, Aaron Sciascia – **Kinetic Chain Contributions to Elbow Function and Dysfunction in Sports**, *Clinics In Sports Medicine* 23(4): 545-552, 2004
- (October 2004) **Publication:** Nina Kuschinsky, Tim Uhl, Aaron Sciascia, Arthur Nitz, Scott Mair, Carl Mattacola - **Muscle Activity Comparison of Four Common Shoulder Exercises in Unstable and Stable Shoulders**, *Journal of Shoulder and Elbow Surgery* 13(5): E1-2, 2004
- (October 2003) **Publication:** Aaron Sciascia, Tim L. Uhl - **Rehabilitative Techniques for Treating Spondylolisthesis**, *NATA NEWS* October: 52-55, 2003
- (April 2003) **Publication:** Aaron Sciascia, Tim Uhl, Carl Mattacola, Jean McCrory, Arthur Nitz, Scott Mair - **Muscle Activity Comparison of Four Common Shoulder Exercises in Unstable and Stable Shoulders**, *Journal of Athletic Training* 38(2): S9, 2003
- (April 2002) **Publication:** Aaron Sciascia, Tim L. Uhl - **Rehabilitative Techniques for Treating Spondylolisthesis**, *Journal of Athletic Training* 37(2): S12, 2002

Publications: Other

- (December 2010) **Publication:** Kibler WB, Sciascia A: **The Role of the Scapula in Shoulder Function**. American Academy of Orthopaedic Surgeons Web site: *Orthopaedic Knowledge Online* 2011;9(1): http://orthoportal.aaos.org/emedial/abstract.aspx?resource=EMEDIA_SPO047. Accessed December 29, 2010.
- (October 2010) **Publication:** Kibler B, Sciascia A: **Core Stability: The Upper Extremity**. American Academy of Orthopaedic Surgeons Web site: *Orthopaedic Knowledge Online* 2010;8(10): <http://www5.aaos.org/oko/slideshowFlash.cfm?topic=SPO043>. Accessed October 25, 2010.
- (August 2010) **Publication:** Kibler B, Sciascia A: **The Shoulder and Beyond: The Kinetic Chain and the Scapula in Shoulder Function and Dysfunction**. American Academy of Orthopaedic Surgeons Web site: *Orthopaedic Knowledge Online* 2010;8(9): <http://www5.aaos.org/oko/description.cfm?topic=SPO011&referringPage=mainmenu.cfm>. Accessed August 30, 2010.
- (August 2010) **Publication:** Kibler B, Sciascia A: **The Kinetic Chain in Function and Dysfunction**. American Academy of Orthopaedic Surgeons Web site: *Orthopaedic Knowledge Online* 2010;8(8): <http://www5.aaos.org/oko/description.cfm?topic=SPO065&referringPage=mainmenu.cfm>. Accessed August 30, 2010.

Presentations: Abstracts

- (October 2016) **Presentation:** Aaron Sciascia, Brent Morris, Cale Jacobs, T. Brad Edwards – **Using Patient-Reported Outcomes to Determine Satisfaction Following Anatomic Shoulder Arthroplasty**, Boston, MA
Podium presentation accepted for presentation at the American Shoulder and

- Elbow Surgeons Annual Meeting (to be presented by T. Brad Edwards)
- (October 2016) **Presentation:** Aaron Sciascia, Cale Jacobs, Brent Morris, W. Ben Kibler – **The Degree of Tissue Injury in the Shoulder Does Not Correlate with Pain Perception**, Boston, MA
Podium presentation accepted for presentation at the American Shoulder and Elbow Surgeons Annual Meeting (to be presented by W. Ben Kibler)
- (June 2016) **Presentation:** Aaron Sciascia, Autumn Whitson, Jordan Light, Tim Uhl – **Influence of History of Shoulder Injury on Perceived and Demonstrable Physical Capability**, Baltimore, MD
Rapid-fire session presented at the 67th National Athletic Trainers' Association Clinical Symposia and AT Expo
- (April 2016) **Presentation:** W. Ben Kibler, Aaron Sciascia – **Biceps Preserving SLAP Repair in Revision Surgery Following Failed Shoulder Arthroscopy**, Boston, MA
E-Poster presented at the Arthroscopy Association of North America Annual Meeting
- (March 2016) **Presentation:** Aaron Sciascia, Cale Jacobs, Brent Morris – **Pain Catastrophizing Behaviors Common in Shoulder Patients with or without Evidence of Local Tissue Derangement**, Orlando, FL
Poster presented at the Orthopaedic Research Society Annual Meeting
- (June 2014) **Presentation:** Aaron Sciascia, Lauren Haegele, Jean Lucas, Tim Uhl – **Establishing Pre-season Self-Reported Functional Outcomes Scores for Athletes**, Lexington, KY
Poster presented at the 65th National Athletic Trainers' Association Clinical Symposia and AT Expo
- (March 2014) **Presentation:** Aaron Sciascia, Lauren Haegele, Jean Lucas, Tim Uhl – **Establishing Pre-season Self-Reported Functional Outcomes Scores for Athletes**, Lexington, KY
Poster presented at the 9th Annual University of Kentucky CCTS Spring Conference
- (April 2013) **Presentation:** W. Ben Kibler, Peter Hester, Aaron Sciascia – **Medial Scapular Muscle Detachment: Clinical Presentation and Surgical Treatment in Athletic Individuals**, San Antonio, TX (presented by W. Ben Kibler)
Poster presented at the Arthroscopy Association of North America Annual Meeting
- (January 2013) **Presentation:** Tim Uhl, Stephanie Moore, Aaron Sciascia, W. Ben Kibler – **Odds of Being Recommended for Surgery following Physical Therapy with a Superior Labral Lesion**, San Diego, CA (presented by Tim Uhl)
Poster presented at the American Physical Therapy Association Combined Sections Meeting
- (June 2012) **Presentation:** Kelley Seekins, Stephanie Moore, Aaron Sciascia, Tim Uhl, W. Ben Kibler – **Compliance to a Standardized Exercise Protocol Positively Affects Patients with Superior Labral Lesions**, St. Louis, MO (presented by Kelley Seekins)
Free communication presented at the 63rd Annual National Athletic Trainers' Association Convention
- (March 2012) **Presentation:** Kelley Seekins, Stephanie Moore, Aaron Sciascia, Tim Uhl, W.

Ben Kibler – **Compliance to a Standardized Exercise Protocol Positively Affects Patients with Superior Labral Lesions**, Atlanta, GA (presented by Kelley Seekins)
Poster presented at the Southeastern Athletic Trainers' Association Clinical Symposium

- (September 2010) **Presentation:** W. Ben Kibler, Craig Morgan, Aaron Sciascia, Tim Uhl **Kinetic Chain Deficits and their Association with Elbow MCL Injury in Overhead Athletes**, Edinburgh, Scotland (presented by Tim L Uhl, PhD)
- (July 2009) **Presentation:** W. Ben Kibler, Craig Morgan, Aaron Sciascia **Kinetic Chain Deficits and their Association with Elbow MCL Injury in Overhead Athletes**, Keystone, CO (presented by W. Ben Kibler, MD)
Poster presented at the American Orthopaedic Society for Sports Medicine Annual Meeting
Awarded 1st Place for Best Poster
- (July 2008) **Presentation:** W. Ben Kibler, Aaron Sciascia, David Dome, Peter Hester, Cale Jacobs **Clinical Utility of New and Traditional Exam Tests for Biceps and Superior Glenoid Labral Injuries**, Orlando, FL (presented by W. Ben Kibler, MD)
Abstract presented at the American Orthopaedic Society for Sports Medicine Annual Meeting
- (March 2008) **Presentation:** W. Ben Kibler, Aaron Sciascia **Medial Scapular Muscle Detachment: Clinical Presentation and Surgical Treatment**, San Francisco, CA (presented by Aaron Sciascia)
Oral presentation presented at the American Academy of Orthopaedic Surgeon's Annual Meeting
- (June 2007) **Presentation:** W. Ben Kibler, Aaron Sciascia **Medial Scapular Muscle Detachment: Clinical Presentation and Surgical Treatment**, Asheville, NC (presented by W. Ben Kibler, MD)
Poster presented at the 120th Annual Meeting of the American Orthopaedic Association
- (June 2007) **Presentation:** W. Ben Kibler, Aaron Sciascia, Tim Uhl, Nishin Tambah, Thomas Cunningham **EMG Analysis of Scapular Strengthening Exercises**, Florence, Italy (presented by W. Ben Kibler, MD)
Poster presented at the 6th Biennial International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS) Congress
- (July 2005) **Presentation:** W. Ben Kibler, Aaron Sciascia, David Dome - **Evaluation of Apparent and Absolute Rotator Cuff Weakness in Shoulder Injury by the Scapular Retraction Test**, Keystone, CO (presented by W. Ben Kibler, MD)
Presented at the American Orthopaedic Society for Sports Medicine Annual Meeting

Presentations: Full Lectures

- (June 2016) **Presentation: Kinetic Chain Evaluation and Rehabilitation** Buffalo, NY
Lab conducted at the Out of the Box but Not Off the Wall: Management of the Shoulder and Scapula closed education meeting
- (June 2016) **Presentation: Perception of Pain: Is it in Our Heads?**, Buffalo, NY
Lecture presented at Out of the Box but Not Off the Wall: Management of the Shoulder and Scapula closed education meeting

- (June 2016) **Presentation: Post-Operative Rehabilitation and Outcomes Following Scapular Muscle Reattachment**, Buffalo, NY
Lecture presented at Out of the Box but Not Off the Wall: Management of the Shoulder and Scapula closed education meeting
- (April 2016) **Presentation: Pain in the Treatment of Scapular Dysfunction**, Lexington, KY
Lecture presented at the 5th Scapula Summit
- (April 2016) **Presentation: Evidence-Based Rotator Cuff Examination for the Practicing Clinician**, Jacksonville, FL
EBP approved session presented at the Jacksonville Sports Medicine Program Annual Symposium
- (April 2016) **Presentation: Return to Play for Overhead Athletes Following Superior Labral Repair**, Jacksonville, FL
EBP approved session presented at the Jacksonville Sports Medicine Program Annual Symposium
- (March 2016) **Presentation: AC Joint Reconstruction Post-Surgical Rehabilitation and Outcomes**, Atlanta, GA
Lecture presented at the Southeast Athletic Trainers' Association Clinical Symposium and Members Meeting
- (March 2016) **Presentation: Perception of Pain: Is it in Our Heads?**, Atlanta, GA
Lecture presented at the Southeast Athletic Trainers' Association Clinical Symposium and Members Meeting
- (October 2015) **Presentation: Post-Operative Rehabilitation and Outcomes Following Scapular Muscle Reattachment**, Asheville, NC
Lecture presented at the American Society of Shoulder and Elbow Therapists 23rd Annual meeting
- (October 2015) **Presentation: Which Patient-Reported Outcome Measure Best Correlates with Satisfaction Following Total Shoulder Arthroplasty?** Asheville, NC
Abstract presented at the American Society of Shoulder and Elbow Therapists 23rd Annual meeting
- (June 2015) **Presentation: Evidence-Based Rotator Cuff Examination for the Practicing Clinician**, Crestview Hills, KY
EBP approved session presented at the Kentucky Athletic Trainers' Society Annual Members Meeting and Symposium
- (June 2015) **Presentation: Return to Play for Overhead Athletes Following Superior Labral Repair**, Crestview Hills, KY
EBP approved session presented at the Kentucky Athletic Trainers' Society Annual Members Meeting and Symposium
- (March 2015) **Presentation: Why and How to Utilize Clinical Outcomes to Improve Clinical Practice**, Atlanta, GA
EBP approved session presented at the Southeast Athletic Trainers' Association Clinical Symposium and Members Meeting
- (January 2015) **Presentation: Why and How to Utilize Clinical Outcomes to Improve Clinical Practice**, Lexington, KY

- EBP approved session presented at the January Kentucky Athletic Trainers' Society Monthly Meeting
- (October 2014) **Presentation: Establishing Pre-Season Self-Reported Functional Outcomes Scores for Overhead Athletes**, Pinehurst, NC
Lecture presented at the American Society of Shoulder and Elbow Therapists 22nd Annual meeting
- (October 2014) **Presentation: Clinical Roundtable – Controversies in the Management of Shoulder Instability**, Pinehurst, NC
Participation in panel discussion at the American Society of Shoulder and Elbow Therapists 22nd Annual meeting
- (August 2014) **Presentation: Return to Pre-injured Levels of Play Following Arthroscopic Labral Repair in Overhead Athletes**, Lexington, KY
Systematic review presented at the 17th Annual Shoulder Center of Kentucky Shoulder Symposium
- (July 2014) **Presentation: Practicing the Evidence-Based Shoulder Exam**, Salisbury, NC
Lab conducted at the North Carolina Athletic Trainers' Association Summer Meeting
- (July 2014) **Presentation: Evidence-Based Shoulder Exam for the Practicing Clinician**, Salisbury, NC
Lecture presented at the North Carolina Athletic Trainers' Association Summer Meeting
- (June 2014) **Presentation: How Helpful are Range of Motion and Manual Muscle Testing in the Clinical Exam of the Shoulder?** Indianapolis, IN
Featured presentation presented at the 65th National Athletic Trainers' Association Clinical Symposia and AT Expo
- (March 2014) **Presentation: Looking Away from the Site of Symptoms**
On-line lecture presented to the senior class of the Messiah College athletic training education program
- (March 2014) **Presentation: A Basic Approach for Common Problems**, Lexington, KY
Lecture presented to the Eastern Little League coaches for injury reduction
- (February 2014) **Webinar: Special Testing of the Shoulder**
Live webinar conducted at the request of the National Athletic Trainers' Association
- (January 2014) **Home Study: Developing and Utilizing Clinical Outcomes Databases in Clinical Practice**
Home study course recorded for the National Athletic Trainers' Association (co-presented with Jennifer Howard, PhD, ATC, University of Kentucky)
- (October 2013) **Presentation: Utilizing Patient Reported Outcomes in Rehabilitation**, Las Vegas, NV
Participation in panel discussion at the American Society of Shoulder and Elbow Therapists 21st Annual meeting
- (June 2013) **Presentation: Return to Play in Overhead Athletes**, Las Vegas, NV
Evidence-Based Forum presented at the 64th Annual National Athletic Trainers' Association Convention

- (January 2013) **Presentation: Recognition and Prevention of Injuries in the Young Athlete**, Lexington, KY
Lecture presented at the Lexington Clinic Update on Pediatric Athletic Injuries
- (August 2012) **Presentation: Recognition and Prevention of Injuries in the Young Athlete**, Lake Cumberland, KY
Lecture presented at the Annual Meeting of the KY Chapter of the American Academy of Pediatrics
- (July 2012) **Presentation: Descriptive Analysis of Patients with Scapular Muscle Detachment**, Lexington, KY
Lecture presented at the 15th Annual Shoulder Center of Kentucky Shoulder Symposium
- (February 2012) **Presentation: A Basic Approach for a Complicated Position**, Lexington, KY
Lecture presented at the 1st Annual International Youth Baseball Coaches Association Summit
- (December 2011) **Presentation: Evaluation of the Upper Extremity Using the Kinetic Chain**, Fayetteville, AR
Lecture and lab presented at the Razorback Sports Medicine Symposium
- (December 2011) **Presentation: Kinetic Chain Principles**, Fayetteville, AR
Lecture presented at the Razorback Sports Medicine Symposium
- (October 2011) **Presentation: The Frequency of Utilization of Clinical Shoulder Exam Tests by Experienced Shoulder Surgeons**, White Sulpher Springs, WV
Presented at the American Society of Shoulder and Elbow Therapists 19th Annual meeting
- (July 2011) **Presentation: Effect of Acute Exposure to Throwing and of Pitching Role on Short Term Shoulder Range of Motion**, Lexington, KY
Lecture presented at the 14th Annual Shoulder Center of Kentucky Shoulder Symposium
- (June 2011) **Presentation: Examination of the Shoulder: Using the Right Tests at the Right Time**, New Orleans, LA
Evidence-Based Forum presented at the 62nd Annual National Athletic Trainers' Association Convention
- (March 2011) **Presentation: Assessment and Treatment of SLAP Lesions**, Atlanta, GA
Lecture and lab presented at 36th Annual Southeastern Athletic Trainers' Association Annual Meeting
- (June 2010) **Presentation: Shoulder Separations and Clavicle Fractures: Biomechanical Considerations for Rehabilitation**, Philadelphia, PA
Workshop presented at the 61st Annual National Athletic Trainers' Association Convention
- (June 2010) **Presentation: Chronic Adaptations of the Throwing Shoulder**, Philadelphia, PA
Featured presentation presented at the 61st Annual National Athletic Trainers' Association Convention
- (October 2009) **Presentation: Post Surgical Treatment Following Scapular Muscle**

- Reattachment**, New York, NY
Presented at the American Society of Shoulder and Elbow Therapists 17th Annual meeting
- (July 2009) **Presentation: Conducting the “Non-Shoulder” Shoulder Examination**, Arlington, TX
Lab conducted at the 55th Southwest Athletic Trainers’ Association Annual Meeting and Clinical Symposium
- (July 2009) **Presentation: Application of the Kinetic Chain Concept through the Entire Rehabilitation Process**, Arlington, TX
Lecture presented at the 55th Southwest Athletic Trainers’ Association Annual Meeting and Clinical Symposium
- (July 2009) **Presentation: Factors Affecting Rotator Cuff Strength**, Lexington, KY
Lecture presented at the 12th Annual Shoulder Center of Kentucky Shoulder Symposium
- (June 2009) **Presentation: The Truth about Supplements**, Danville, KY
Lecture presented at the Kentucky High School Athletic Association Coach’s Medical Symposium
- (June 2009) **Presentation: Treating the Findings of the “Non-Shoulder” Shoulder Exam**, San Antonio, TX
Workshop presented at the 60th Annual National Athletic Trainers’ Association Convention
- (June 2009) **Presentation: The Truth about Supplements**, London, KY
Lecture presented at the Kentucky High School Athletic Association Coach’s Medical Symposium
- (June 2009) **Presentation: The Frequency of Utilization of Clinical Shoulder Exam Tests by Experienced Shoulder Surgeons**, Newport, KY
Lecture presented at the Kentucky Athletic Trainers’ Society Annual Meeting
- (June 2009) **Presentation: Clinical Utility of New and Traditional Tests for Biceps and Superior Labral Injuries**, Newport, KY
Lecture presented at the Kentucky Athletic Trainers’ Society Annual Meeting
- (September 2008) **Presentation: Nutrition Aspects**, Barbourville, KY
Lecture presented to the student-athletes, coaching staff, and athletic training staff at Union College
- (August 2008) **Presentation: Conducting the Non-Shoulder Exam**, Morton Grove, IL
Lecture presented to the physical therapists and physicians of the Illinois Bone and Joint Institute
- (August 2008) **Presentation: Research Update**, Morton Grove, IL
Lecture presented to the physical therapists and physicians of the Illinois Bone and Joint Institute
- (July 2008) **Presentation: Presence of GIRD in Baseball Pitchers**, Lexington, KY
Preliminary data presented at the 11th Annual Shoulder Center of Kentucky Shoulder Symposium
- (July 2008) **Presentation: Conducting the Non-Shoulder Exam**, Lexington, KY

- Lecture presented at the 11th Annual Shoulder Center of Kentucky Shoulder Symposium
- (June 2008) **Lead Discussant: Special Interest Group – The Overhead Pediatric Athlete**, St. Louis, MO
One of two discussants of special interest group at the 59th Annual National Athletic Trainers' Association Convention
- (June 2008) **Presentation: Conducting the Non-Shoulder Exam**, St. Louis, MO
Clinical session presented at the 59th Annual National Athletic Trainers' Association Convention
- (June 2008) **Presentation: The Truth about Supplements**, London, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (June 2008) **Presentation: Recovery in Athletics**, London, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (October 2007) **Presentation: Nutrition Aspects**, Williamsburg, KY
Lecture presented at monthly student convocation at the University of the Cumberlands
- (October 2007) **Presentation: Shoulder Pain in the Working Population**, Lexington, KY
Presented lecture to Case Managers Society of America Bluegrass Chapter
- (July 2007) **Presentation: Correlation of Physical Exam and Surgical Findings**, Lexington, KY
Research study presented at the 10th Annual Lexington Clinic Sports Medicine Center Shoulder Symposium
- (June 2007) **Presentation: The Role of Core Stability in Athletics**, Danville, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (June 2007) **Presentation: The Effect of Humeral Abduction Angle on a Clinical Measure of Glenohumeral Internal Rotation Deficit in Throwing Athletes**, Anaheim, CA
Oral presentation presented at the 58th Annual National Athletic Trainers' Association Convention (given by lead author P. Dwelly)
- (June 2007) **Presentation: Staff Communication**, London KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (April 2007) **Presentation: The Non-Shoulder Shoulder Examination**, Laurium, MI
Lecture presented to physical therapy and medical staff at Keweenaw Memorial Hospital
- (April 2007) **Presentation: Role of the Scapula**, Laurium, MI
Lecture presented to physical therapy and medical staff at Keweenaw Memorial Hospital
- (April 2007) **Presentation: Surgical Summation**, Laurium, MI
Lecture presented to physical therapy and medical staff at Keweenaw Memorial

Hospital

- (March 2007) **Presentation: The Effect of Humeral Abduction Angle on a Clinical Measure of Glenohumeral Internal Rotation Deficit in Throwing Athletes**, Nashville, TN
Poster presented at the 2007 Southeastern Athletic Trainers' Association Annual Research Seminar (Presented by lead author P. Dwelly).
- (October 2006) **Presentation: Shoulder Rehabilitation and the Kinetic Chain**, Florence, Italy
Lecture presented at the 2nd International Course on Functional Rehabilitation and Sports
- (October 2006) **Presentation: Shoulder Evaluation**, Florence, Italy
Lecture presented at the 2nd International Course on Functional Rehabilitation and Sports
- (October 2006) **Presentation: Shoulder Rehabilitation and the Kinetic Chain**, Florence, Italy
Lab presented at the 2nd International Course on Functional Rehabilitation and Sports
- (August 2006) **Presentation: Conditioning and Injury Prevention in Tennis**, White Sulphur Springs, WV
Lecture presented at the Society for Tennis Medicine and Science Annual Meeting
- (June 2006) **Presentation: Low Back Problems in Athletics**, Danville, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (June 2006) **Presentation: Nutrition for the Modern Athlete**, London, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (June 2006) **Presentation: What Makes the Ball Go**, London, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (July 2005) **Presentation: Scapula Research**, Lexington, KY
Two research studies presented at the Lexington Clinic Sports Medicine Center's 8th Annual Shoulder Symposium - The Shoulder in the Overhead Athlete: Advanced Evaluation and Treatment
- (July 2005) **Presentation: Evaluation of Apparent and Absolute Rotator Cuff Weakness in Shoulder Injury by the Scapular Retraction Test**, Keystone, CO
Abstract presented at the American Orthopaedic Society for Sports Medicine Annual meeting (Presented by lead author WB Kibler)
- (June 2005) **Presentation: Shoulder Biomechanics and the Kinetic Chain**, Danville, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (June 2005) **Presentation: Principles of Conditioning Programs**, London, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (June 2005) **Presentation: Nutrition Concepts**, London, KY

- Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (November 2004) **Presentation: Joint Mobilization**, Richmond, KY
Lecture presented to the Eastern Kentucky University Athletic Training Education Program
- (November 2004) **Presentation: Evaluation of the Lumbar Spine and SI Joint**, Richmond, KY
Lecture presented to the Eastern Kentucky University Athletic Training Education Program
- (November 2004) **Presentation: Evaluation of the Cervical and Thoracic Spine**, Richmond, KY
Lecture presented to the Eastern Kentucky University Athletic Training Education Program
- (September 2004) **Presentation: Shoulder Biomechanics and the Kinetic Chain**, Richmond, KY
Lecture presented to the Eastern Kentucky University Athletic Training Education Program
- (June 2004) **Presentation: Shoulder Biomechanics and the Kinetic Chain**, Danville, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (June 2004) **Presentation: Nutrition Concepts**, London, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (May 2004) **Presentation: Muscle Activity Comparison of Four Common Shoulder Exercises in Unstable and Stable Shoulders**, Washington, DC
Oral presentation presented at the First International Congress of Shoulder Therapists (Presented by TL Uhl)
- (March 2004) **Presentation: Muscle Activity Comparison of Four Common Shoulder Exercises in Unstable and Stable Shoulders**, Atlanta, GA
Poster presented at the 2004 Southeastern Athletic Trainers' Association Annual Research Seminar.
- (June 2003) **Presentation: Muscle Activity Comparison of Four Common Shoulder Exercises in Unstable and Stable Shoulders**, St. Louis, MO
Oral communication presented at the National Athletic Trainers' Association 54th Annual Symposium (Presented by TL Uhl).
- (June 2003) **Presentation: Environmental Considerations in Athletics**, London, KY
Lecture presented at the Kentucky High School Athletic Association Coach's Medical Symposium
- (June 2002) **Presentation: Rehabilitative Techniques for Treating Spondylolisthesis**, Dallas, TX
Oral communication presented at the National Athletic Trainers' Association 53rd Annual Symposium.
- (March 2002) **Presentation: Rehabilitative Techniques for Treating Spondylolisthesis**, Atlanta, GA
Poster presented at the 2002 Southeastern Athletic Trainers' Association Annual Research Seminar.

(Aug 2001)

Presentation: Treatment of Soccer Injuries, Frankfort, KY
Lecture presented at the Soccer Sensations seminar.

(June 2001)

Presentation: Nutrition for the Modern Athlete, Danville, KY
Lecture presented at the Kentucky High School Athletic Association Medical Symposium

Current Research

- Satisfaction Following Anatomic and Reverse Total Shoulder Arthroplasty
- Serve Volume in Professional and Junior Level Tennis Athletes
- Pain Response and Management Following Shoulder Surgery
- Prospective Assessment of Return to Pre-Injured Levels of Activity
- Survey of Clinical Examination and Surgical Treatment of High Grade AC Injury
- Functional Outcomes of Post-Operative and Non-Operative Physical Therapy Patients
- Post-Surgical Outcome of Patients with Medial Scapular Muscle Detachment
- Post-Surgical Outcomes Following AC Joint Reconstruction
- Outcomes Following Orthopedic Knee or Shoulder Surgery

Funding

- Legacy Grant: American Physical Therapy Association, Sports Section \$8,230.00
 - Using Prospective Outcome Measures to Determine the Risk of Re-injury
 - Notification of award: February 2016
 - Anticipated start of study: August 2016
- Lexington Clinic Foundation \$14,470.00
 - Does patient pre-operative perception of pain influence post-operative clinical outcome following shoulder surgery?
 - Notification of award: February 2016
 - Anticipated start of study: June 2016

Certifications

- National Athletic Trainers Association Board of Certification certified: Certification # 060002512 – June 2000
 - Kentucky Board of Medical Licensure: Certification # AT440 – December 2000
 - National Provider Identifier # 1508841578 – December 2005
 - National Athletic Trainers' Association Board of Certification Practical Examiner – January 2002 to April 2007
- Basic Life Support CPR/AED Certified Instructor – AHA certified May 2006 to present
 - Basic Life Support for Healthcare Providers: CPR/AED certification – AHA certified January 2016
- Approved Clinical Instructor Eastern Kentucky University – January 2006 to December 2012
- National Academy of Sports Medicine Performance Enhancement Specialist – August 2008
- Nutrition Specialist Certification: American Academy of Sports Dietitians and Nutritionists (formerly Lifestyle Management Associates) – July 2004 to December 2009
- Yellow Belt Certification: Lean Six Sigma Program – July 2015

Peer Reviewer Assignments

- Peer Reviewer: Journal of Sport Rehabilitation – June 2007, September 2007, January 2010, May 2010, December 2010, August 2012, May 2013, May 2014, September 2014, April 2015, October 2015, March 2016
- Peer Reviewer: Clinical Anatomy – December 2008, February 2009, August 2011, February 2013
- Peer Reviewer: Acta Astronautica – January 2009
- Peer Reviewer: International Journal of Sports Medicine – July 2009, September 2010, January 2013
- Peer Reviewer: British Journal of Sports Medicine – September 2009, December 2009, January 2013, June 2013
- Peer Reviewer: Journal of Athletic Training – September 2009, January 2010, April 2010, June 2011, May 2012, April 2014, August 2014, October 2015, April 2016, August 2016
- Peer Reviewer: Clinical Journal of Sports Medicine – September 2010, April 2012, December 2013, May 2015, December 2015, June 2016, August 2016
- Peer Reviewer: Physical Therapy in Sport – November 2010
- Peer Reviewer: Rehabilitation Research and Practice – October 2011
- Peer Reviewer: World Journal of Orthopedics – October 2012, June 2013, February 2015
- Peer Reviewer: Sports Health – December 2012, February 2014, August 2016
- Peer Reviewer: Journal of Applied Biomechanics – January 2013
- Peer Reviewer: American Journal of Sports Medicine – February 2013
- Peer Reviewer: Clinical Biomechanics – March 2013, April 2015
- Peer Reviewer: BMC Sports Science Medicine and Rehabilitation Research – May 2013
- Peer Reviewer: International Journal of Athletic Therapy and Training – June 2013, August 2013, August 2014
- Peer Reviewer: Prosthetics and Orthotics International – February 2014
- Peer Reviewer: Scandinavian Journal of Medicine and Science in Sport – July 2014, November 2014
- Peer Reviewer: The Physician and Sports Medicine – February 2015

Organizations

- National Athletic Trainers' Association – 1999 to present
- Kentucky Athletic Trainers' Society – 2000 to present
- Southeastern Athletic Trainers' Association – 2000 to present
- American Society of Shoulder and Elbow Therapists – 2009 to present
- Vineyard Community Church Richmond – 2012 to present

Organizations (past)

- National Strength and Conditioning Association – 2004 to 2006
- American College of Sports Medicine Alliance – 2006
- American Academy of Sports Dietitians and Nutritionists (formerly Lifestyle Management Associates) – 2004 to 2009
- First Christian Church (Disciples of Christ) Richmond – 2008 to 2011

Professional Positions Held

- Kentucky Athletic Trainers' Society Secretary – July 2008 to December 2011
- Kentucky Athletic Trainers' Society Webmaster – August 2012 to present
- Kentucky Advisory Council on Athletic Trainers – Appointed by Governor Steve Beshear (term 2009-2013), renewed (term 2013-2017)
- American Society of Shoulder and Elbow Therapists Communication Chair – November 2010 to October 2014
- American Society of Shoulder and Elbow Therapists Member at Large – October 2012 to October 2014

- American Society of Shoulder and Elbow Therapists Secretary/Treasurer Elect – October 2014 to October 2015
- American Society of Shoulder and Elbow Therapists Secretary/Treasurer – October 2015 to present
- Southeastern Athletic Trainers' Association Evidence-Based Practice Coordinator – June 2014 to March 2016

Personal Positions Held

- First Christian Church Disciples of Christ Diaconate – January 2010 to December 2010
- First Christian Church Disciples of Christ Elder – January 2011 to December 2011
- First Christian Church Disciples of Christ Board Vice-Chair – June 2010 to December 2010
- First Christian Church Disciples of Christ Board Chair – January 2011 to December 2011
- Vineyard Community Church Richmond Finance Team – June 2013 to present
- Vineyard Community Church Richmond Treasurer – November 2013 to present

Honors and Awards

- Kentucky Athletic Trainers' Society Clinical Athletic Trainer of the Year – June 2014
- Exceptional Customer Service Recognition (Lexington Clinic) – August 2014
- Kentucky Athletic Trainers' Society Award of Merit – June 2015
- American Society of Shoulder and Elbow Therapists Founders' Award – October 2015
- University of Kentucky College of Health Sciences Robinson Graduate Award for Research Creativity – April 2016