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The Relationship Between Landing Error Scoring System-Real Time and Dorsiflexion Range of Motion in Recreational Athletes

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THE RELATIONSHIP BETWEEN LANDING ERROR SCORING SYSTEM-REAL TIME AND DORSIFLEXION RANGE OF MOTION IN RECREATIONAL ATHLETES

by

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ABSTRACT

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Participation in physical activity is important for overall health; however, lower extremity injuries are a major risk associated with physical activity. Injuries can lead to time away from physical activity and be associated with negative health consequences. The most common injuries are traumatic injuries to the knee and ankle; which may be related to poor landing mechanics and decreased range of motion. Previous research utilizing motion analysis systems have determined people with greater dorsiflexion range of motion (DROM) demonstrated smaller ground reaction forces and greater knee and hip flexion displacement while landing; indicating a softer landing strategy. The ability to screen for landing mechanics and range of motion deficiencies is an important step in the prevention of physical activity related injuries. Therefore, the purpose of this thesis was to examine the relationship between jump landing biomechanics and DROM utilizing real-time, field-based assessments in recreational athletes.

Thirty-six collegiate club soccer and basketball athletes participated in a single testing session. Jump-landing mechanics were assessed with the Landing Error Scoring System-Real Time (LESS-RT) and DROM was measured with the Weight Bearing Lunge Test (WBLT). Spearman's rank correlations identified a weak, insignificant relationship between the WBLT summary and LESS-RT ($r = 0.11$, $p = 0.52$). Although a significant relationship was not identified, scores from individual items on the LESS-RT related to knee flexion, trunk flexion,

and knee valgus were the primary contributors to poor landing mechanics and warrant further examination. Although these findings do not support previous laboratory studies, it appears the LESS-RT and WBLT may provide unique information to be considered when examining injury risk. We reject the hypothesis that there would be a relationship between LESS-RT and WBLT; however, measures of DROM and LESS-RT items in these recreational sport participants revealed areas of further examination for these lower extremity assessments.

This thesis is dedicated to the coffee that got me through this and
to my friends and family for the support and encouragement
throughout this process.

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NOMENCLATURE

ACL	Anterior Cruciate Ligament
AKFD	Amount of Knee- flexion Displacement
ALTF	Amount of Lateral Trunk Flexion
ATFD	Amount of Trunk-flexion Displacement
DROM	Dorsiflexion Range of Motion
IFC	Initial Foot Contact
ILF	Initial Landing of Feet
LESS	Landing Error Scoring System
LESS-RT	Landing Error Scoring System- Real Time
MFP	Maximum Foot-rotation Position
MKV	Maximum Knee-valgus Angle
MSOC	Men's Club Soccer Subjects
OI	Overall Impression
PA	Physical Activity, (No Units)
SW	Stance Width
TJD	Total Joint Displacement in the Sagittal Plane
WBB	Women's Club Basketball Subjects
WBLT	Weight Bearing Lunge
WBLT-Symmetry	Weight Bearing Lunge Symmetry Score
WBLT-Total	Weight Bearing Lunge Total Score
WSOC	Women's Club Soccer Subjects

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CHAPTER ONE

INTRODUCTION

BACKGROUND

Participation in at least 30 minutes of physical activity (PA) results in significant health benefits such as a 36% lower risk of cardiovascular disease mortality (4). In addition, participation in regular PA can be a primary or secondary prevention tool for chronic diseases such as cardiovascular disease, diabetes, cancer, hypertension, obesity, depression, osteoporosis, and stroke (4). Regular participation in PA can also enhance mental and social health outcomes (28, 64). For college age individuals, sport participation is a common form of PA, and can vary from intramural team or recreational sport league to intercollegiate athletic team participation. Approximately 50% of the student population of college-aged individuals, who are not part of intercollegiate athletics, participate in recreational sport leagues as their primary mode of PA (49). Sport leagues, such as intramurals or club sports, are common on most college campuses to provide young adult, recreational athletes the ability to participate in organized, competitive sports.

While PA has numerous health benefits, participation in sport PA increases the risk for musculoskeletal injury. There is minimal literature describing the epidemiology of musculoskeletal injuries for the recreational athlete population. However, epidemiology data for 15 intercollegiate sports reported 51% of injuries are to the lower extremity (8). The American College of Sport Medicine (ACSM) determined half of all lower extremity injuries suffered while participating in sports are ankle related, with approximately 25,000 athletes suffering an ankle sprain each day (41). Of even more concern is an estimated 70% of ankle sprains lead to chronic ankle instability, a chronic condition of repetitive giving way and feeling of instability which can cause a decrease in function and participation in PA within the young-adult population (41). After an injury, it has been reported college-age recreational athletes suffer from depression, anger, increased tension, and less vigor than college norms (58). Furthermore, a recent study demonstrated the majority of recreational athletes were not concerned with long-term consequences of sport-related injuries and the participants reported they would not seek medical advice after sustaining a musculoskeletal injury (33). Recreational athletes are more likely to seek advice from teammates and online resources, with limited awareness of potential future injury risk (33). However, recreational athletes are concerned with the short-term consequences of an injury which prevent them from participating in their recreational PA (33). Furthermore, they believe the benefits of participation in recreation sport far outweigh the injury risk and are likely to continue to exercise, even after a previous injury was sustained (33). Thus, there is a need for improved self-education for individuals who participate in recreational PA to decrease the risk of lower extremity musculoskeletal injury and prevent adverse effects (41). The identification of risk factors that could predispose an individual to sport-related injuries should be evaluated to allow for better education for recreational athletes who participate in PA.

Lack of awareness, improper movement patterns, and muscle weakness can increase instances of sustaining an injury. Ankle plantar flexors and knee extensors are the primary muscle groups responsible for dissipating the body's kinetic energy during a landing task, followed by hip extensors (23). Erect landing posture or "stiff" landing with limited hip and knee displacement and reduced ankle dorsiflexion (DROM) causes an increased force absorption at the ankle (23). Increased lower extremity stiffness during a landing task is also associated with increased peak forces and loading rates which decreases shock absorption (17). Additional factors which influence poor landing biomechanics are poor muscle activation and strength often associated with knee valgus, knee flexion, and ankle DROM (46). Greater DROM has been found to have a strong relationship with jump landing mechanics assessed using a 3D motion analysis system (30). Individuals with greater DROM demonstrated smaller ground reaction forces and greater knee and hip flexion displacement while landing; indicating a softer landing strategy (30). Less knee flexion displacement is a risk factor for knee injury and ankle injury occurring during a jump landing task (30). Because of the inability to absorb shock, poor lower body mechanics during sport activities increases an individual's risk for injury (30). Thus the utilization of screening tools which examine an individual's landing mechanics is necessary to identify individuals at a greater risk for lower extremity injury. Once these individuals are identified, they can be provided an injury prevention program to improve their landing mechanics and/or range of motion deficits in order to decrease lower extremity injury rates in recreational PA.

PROBLEM

Current literature regarding injury risk and prevention screening has primarily evaluated elite or intercollegiate athletes, with little research focused on recreational athletes. The Surgeon General's report found the major negative consequence of an increase in PA is the risk of sustaining a musculoskeletal injury (48). The report went on to give general recommendations for increasing PA while minimizing injury risk through: sufficient warm-up sessions of at least 5-10 minutes, availability of appropriate sport equipment, correct sport techniques, understanding of the body's physical abilities, proper hydration, and having an appropriate cool down (48). While these recommendations were aimed at preventing general injuries from occurring; injury risks specific to the individual or sport were not included for individuals participating in recreational sports. The need for a screening assessment to determine specific injury risk for individuals participating in PA is necessary to allow recreational athletes in continuing to reap the benefits of recreational activity. Furthermore, the refinement of current screening techniques to effectively and efficiently screen a large number of recreational college athletes is warranted. Specifically, there is a need to identify screening techniques that can be used in real time with a large group of individuals to identify those at risk and provide injury prevention exercises to decrease injury risk. The customization of these assessments to be used within a recreational facility will allow for better education and participation within recreational PA.

Utilizing laboratory measures, greater DROM has been found to have a strong relationship with jump landing mechanics (30). However, given the large number of individuals who participate in recreation PA, lower extremity assessments that can be used in real-time, mass screenings are needed. The Landing Error Scoring System- Real Time (LESS-RT) and Weight Bearing Lunge Test (WBLT) are two real-time screening techniques that can be used to assess DROM and landing mechanics in physically active individuals. These real-time assessments may be a beneficial means to assess injury risk through large-group screenings in a recreational facility (55).

PURPOSE OF THE STUDY

The purpose of this study is to determine the relationship between scores on the LESS-RT and DROM in college age recreational athletes who participate in recreational basketball and soccer. Basketball and soccer recreational athletes were selected as a focus of the study as these sports have the highest risk of lower extremity injury.

HYPOTHESIS

It is hypothesized there will be a moderate relationship between LESS-RT and DROM scores in recreational athletes. Individuals with decreased DROM will have a higher score on the LESS-RT.

OPERATIONAL DEFINITIONS

Recreational activity- An activity that people engage in during their free time and recognize as having socially redeeming values: participants hope the recreational activity helps balance their lives (40)

Recreational athlete- A person who regularly participates in seasonal sport activities; an individual who participates on a sport team at a recreational level three times or less per week, but does not follow a professionally designed training regime; many participate in intramural level or sport club in collegiate recreation (19, 60)

Sport Clubs- A student led organizations for students who share a common interest in a particular sport. The participants run all aspects of the club. The participants meet regularly to participate in the sport, but not as often as varsity teams. It is classified as either competitive or noncompetitive based on skill levels and interest of the student participants. Competitive clubs compete in various state, regional, and national contests against other university/college clubs (26)

Intramural sports- Programs provided to university and college students as an opportunity to participate in a variety of competitive and recreational sport activities. There are different leagues such as noncompetitive or competitive, and co-recreational. Participants typically do not practice, and only meet for regular scheduled games during the sport season (26)

Sport injury- An injury that results from acute trauma or repetitive stress associated with athletic activities. They can affect bones or soft tissue such as ligaments, muscles, and tendons (5)

Landing Error Scoring System – Real Time (LESS-RT)- A clinical tool to assess jump-landing biomechanics in real time (55)

Ankle dorsiflexion range of motion (DROM)- Flexion of the foot at the ankle for the foot to point more superiorly (3)

Weight Bearing Lunge Test (WBLT)- Clinical tool to assess ankle dorsiflexion range of motion (13)

CHAPTER 2

REVIEW OF LITERATURE

PHYSICAL ACTIVITY GUIDELINES

Physical activity is vital for maintaining a healthy lifestyle. Participation in regular PA aids in weight control, strengthens muscles and bones, improves mental health, and increases an individual's ability to perform activities of daily living and life expectancy (4). Physical activity decreases the risk of many health diseases such as cardiovascular disease, Type 2 diabetes and metabolic syndrome, and certain types of cancers (4). According to the CDC, PA should begin during childhood and continue throughout adulthood in order for an individual to reap the full benefits associated with being physically active (4). The CDC's recommendation for ages 7-17 years-old is to participate in 60-minutes or more of aerobic activity of any intensity, 7-days a week (4). The CDC also encourages muscle and bone strengthening to be included 3-days a week in the form of gymnastics, push-ups, jump rope, or running (4). The PA recommendation for individual's ages 18-64 years old is 150-minutes a week of moderate-intensity aerobic PA or 75-minutes a week of vigorous-intensity aerobic PA (4). Examples of moderate-intensity PA include brisk walking, water aerobics, tennis, and gardening. Examples of vigorous-intensity PA include jogging or running, swimming laps, jumping rope, hiking, and bicycling. Adults should also participate in muscle and bone strengthening 2 or more days a week including 2-5 sets of 8-12 repetitions for all major muscle groups (4). There are different types of exercises that can be performed for muscle strengthening including lifting weights, resistance band training, body weight exercises, and yoga (4). Individuals ages 65 years and older have the same PA guidelines as younger adults. Older adults should include balance training, functional training, and walking aerobic activities in their daily routine (4).

It has been estimated only 35% of women and men ages 18-24 yrs. meet the minimum guidelines for moderate PA of completing at least 30 minutes or more of moderate-intensity PA on most days of the week (65). About 40-50% of college students are not physically active (42). As students transition into college, the independence of not being required or having pressure to participate in regular PA allows many to choose other modes of PA rather than traditional modes of PA (1). Additional modes of PA such as recreational, competitive sport participation through intramurals or sport clubs, combine many dimensions of wellness which have been found beneficial to college students (1).

A study conducted at Purdue University found college students who exercised at least once a week earned a higher grade point average when compared to students who did not participate in PA (53). Physical activity has been linked to brain cell development, memory retention, increased focus and concentration, decreased stress, and increased mood in college students (32). These benefits are especially needed throughout the college years, as packed schedules and an increased workload can lead to more stress (39). Within the college setting, there are many opportunities to participate in PA that aid in social and emotional wellbeing, as well as academic success. For example, at a college or university, there are numerous opportunities to participate in PA including intramurals, sport clubs, sport tournaments, rock climbing, outdoor programs and swimming. Intramurals and sport clubs are beneficial as they allow students to not only receive the benefits from participating in PA, but also reap the benefits of social participation. A study comparing participation in collegiate intramurals and student success identified students who participate in collegiate recreation activities to have greater stress reduction, higher self-esteem, enhanced GPA, increased student development, and more social participation (9). Intramurals and sport clubs are the more popular extracurricular activities on college campuses because of the many benefits to college students (9). Unfortunately, those who participate in intramurals and sport clubs do not have proper coaching or training and often do not take proper care of their bodies to prevent injuries (33). Limited training becomes a major issue for those that participate in intramural and sport clubs for health benefits after sustaining an injury, because many do not take the proper steps to heal and decrease their risk for sustaining another injury (33).

MUSCULOSKELETAL INJURY

Musculoskeletal injuries associated with participation in intramural sports have been examined previously. A study on 8 intramural sports identified an injury rate of 5.56 (CI= [4.67,6.61] injuries per 100 participants (49). The intramural and sport club injury assessments focused on flag football, softball, floor hockey, volleyball, basketball, ultimate frisbee, and soccer (49). The data revealed basketball players had the highest overall injury rate while soccer had the highest number of lower extremity injuries (49). Ankle and knee injuries are the most common injuries after minor abrasions in recreational athletes. It has been determined that 51% of all injures occurring during basketball, soccer, and football are to the ankle (8). Another major lower extremity injury associated with soccer and basketball is a tear of the anterior cruciate ligament (ACL) (38).

Furthermore, in study on 15 collegiate sports, preseason sport injury rates are 2.5-5.5 times higher than in-season and post-season rates, which is thought to be due to the athletes level of physical fitness and the stress of high-intensity, high-load training (38). Preseason male soccer players suffer 7.98 preseason injuries versus 2.43 non-preseason injuries per 1000 athletic-exposures (6). Female soccer players suffer a 3 times greater rate for injuries during the pre-season versus in-season (25). Female and male basketball preseason-practice injury rates were more than twice as high as regular-season practice rates (7, 24).

*Knee Injury (ACL)***.** Non-contact injuries are those that occur when no direct contact occurs between players. These injuries happen when an athlete is quickly decelerating, landing unbalanced, and pivoting (15). Three-dimensional kinematics of the lower extremity and trunk during these at-risk activities has been able to characterize risk factors (59). These risk factor characteristics include increased posterior-directed ground reaction force, anterior-director sheer force, increased internal/external rotation, and varus/valgus moments at the knee; all common mechanisms associated with noncontact injury to the ACL (66). Unfortunately, laboratory based motion-analysis testing is expensive, complex, and not easy to administer as a large-scale screening tool (59). The Landing Error Scoring System (LESS) is a reliable and valid screening tool to identify individuals at a higher risk of sustaining a noncontact ACL injury (59). The LESS was developed to screen for at-risk characteristics of a drop landing task and to evaluate movement patterns in the sagittal, frontal, and transverse planes (55). The LESS assesses lower extremity positioning at the point of initial contact with ground, maximum flexion, fluidity, and range of motion from a landing task (55).

ACL injury risk characteristics evaluated through the LESS assessment are stance width, foot position and contact, knee valgus, lateral trunk flexion, knee and hip displacement, and total joint displacement (55). Stance width and lateral trunk flexion are associated with side-to-side cutting tasks influencing the body's center of mass relative to the knee joint causing a greater knee-valgus moment and greater external knee-flexion with internal-rotation (22). Another noncontact injury risk is asymmetric foot contact (one foot contacts ground before the other) which increases the initial load on the first limb to contact the ground (54). Another aspect of foot contact is heel-to-toe landing which results in smaller dorsiflexion, knee flexion, and hip flexion displacement with greater ground-reaction forces (23). Foot internal or external rotation upon contact with the ground determines tibial rotation, which in excess in either direction is known to produce greater ACL loading (54). Knee valgus or medial knee displacement (knock knees) is caused by hip adduction and internal rotation causing the knee to move medially relative to the foot (2). Women are more prone to knee valgus because of an increased Q-angle; an angle made from connecting the anterior superior iliac spine to the midpoint of the patella and connecting the tibial tuberosity superiorly through the midpoint of the patella (46). Other causes for increase knee valgus are weak gluteal/hip strength, inadequate ankle dorsiflexion mobility, and impaired quadriceps and hamstring function (46). Knee and hip flexion is assessed with the LESS to evaluate the individual's posture upon contact. Less knee, hip, and trunk flexion is associated with increased vertical ground-reaction forces indicating a "stiff" landing (23). Collegiate female basketball players demonstrate less knee flexion at initial contact causing a more erect landing posture, increased joint forces, and a greater risk of injury (52). Specifically, decreased knee flexion is associated with greater quadriceps-induced, anterior tibial shear force limiting the ability of the hamstring to offset the sheer forces (45). These injury risk characteristics associated with lower extremity injuries (such as knee valgus and knee flexion) are combined during at-risk movements causing a greater increase in incidence of suffering an ACL injury (47, 66).

Ankle Injury. Ankle injuries are among the most common injuries associated with basketball and soccer with 41% of all sport related ankle sprains occurring while playing basketball and 17-20% of injuries suffered while playing soccer (29, 50). Within a male soccer population, lower level competition report a slightly higher ankle sprain rate of 2 per 1000 exposures compared to elite male soccer players who reported 1.7 ankle sprains per 1000 exposures (29). Overall, male soccer players of a lower division reported a lower total number of ankle sprains (n=24) compared to Division I (n=51) and Division II (n=59) athletes (29). Following the initial ankle sprain, athletes are almost 5 times more likely to sustain another ankle injury (65). A study conducted on 100 soccer players identified approximately 71% of ankle injuries occurred from noncontact foot supination during landing and cutting (11). Individuals with muscle strength imbalances such as elevated eversion-to-inversion ratio, greater plantar flexion strength, and smaller dorsiflexion-to-plantar flexion ratio increased the incidence of an inversion ankle sprain (11). In addition, coupling of lower extremity joints indicates that an increase or decrease movement at one joint is accompanied by greater movement at an adjacent joint; thus the function from all joints effect landing force absorption (23, 30). Fong et al. determined individuals with greater DROM demonstrate smaller ground reaction forces and greater knee-flexion displacement to allow for a soft jump landing (30). Measures of DROM have been related to injury risk characteristics associated with ACL injury through landing posture and ground reaction force data (30).

Sagittal plane video analysis and ground reaction force data on intercollegiate basketball and volleyball players determined muscle contributions from the lower extremity to absorb landings in the stiff and soft posture (23). During a soft landing, hip and knee extensors absorb about 50% more energy compared to 12% less absorption from the ankle (23). Therefore, softer landings are associated with greater energy dissipation throughout the lower extremity. Greater energy dissipation at the ankle during a soft landing is associated with greater DROM and greater sagittal-plane joint displacement (30). Increased sagittal-plane joint displacement increases the duration of the loading phase allowing for more muscle dissipation time and reduced muscular-force contributions (30). Erect landing posture or “stiff” landing with limited hip and knee displacement and reduced DROM causes an increased force absorption at the ankle (23).

INJURY SCREENING ASSESSMENTS

Due to the short-term physical and mental health impairments and long-term consequences associated with lower extremity injury, it is important to utilize screening tools to identify risk factors that predispose individuals to injury. Within a sport injury risk profile, there are four categories: biological (conditioning, biomechanics, overtraining, fatigue, maturation, prior injury), physical (weather, equipment, facility, playing surface), psychological (life event stress, mood state, attitudes), and sociocultural (sport norms, coaching quality, officiating, cultural context). These four categories are categorized into internal (personal) and external (environmental) groups (35). The main variable that is modifiable is biological, which is a warranted focus for injury risk assessments and prevention strategies (35).

Recreational athletes have limited resources regarding the prevention of musculoskeletal injuries. Assessing an individual's risk will provide the knowledge needed to understand their injury risk, prevent an injury, and maintain their PA. Injury risk profiles can aid clinicians in the development of injury-prevention and rehabilitation programs. However, many lower extremity assessment tools are time-consuming, expensive, complex, and are not able to be performed on groups. To better utilize injury risk screenings with recreational athletes, there is a need for reliable and valid assessment tools which are simple and less demanding to permit mass screenings with real time analysis (55). Real-time analysis allows for immediate data collection, unlike many sport-specific assessments which utilize 3-D motion analysis and video recording (55). The Functional Movement Screen is a real time analysis of the lower body, but it does not assess an individual on a sport-specific task such as a jump landing, which is typically associated with lower extremity injures (54). Usually studies assessing jump landing tasks and other sport-specific tasks require video camera, force plates, and 3-D motion capture equipment (55). However, other assessments such as the tuck jump which do not require expensive equipment and have been determined to be a reliable tool, require a very high effort load on the athlete potentially fatiguing the athlete and increasing a stressed landing (27). The LESS does not increase stress or fatigue on the participant while still providing a real-time analysis of known injury risk characteristics associated with lower-extremity injuries (55).

The Landing Error Scoring System-Real Time (LESS-RT). ACL injuries are commonly associated with increased knee valgus motion, decreased knee flexion, and decreased dorsiflexion range of motion (46). Movement patterns for noncontact ACL injuries have been determined through dynamic assessments of the drop-landing task (59). The drop landing task allows researchers to assess many of the factors associated with ACL injuries within one assessment (59). The LESS was developed as a standardized tool to meet the need of real-time analysis (59). The LESS utilizes 2 cameras in the frontal and sagittal plane to record an individual as they jump from a 30-cm box to a mark set to a distance 50% of their height (59). The full LESS utilizes results from 17 scored items, as well as a video analysis to determine landing techniques (56). However, to allow for quicker assessment, the modified LESS- RT evaluates 10 landing characteristics to include the individual's knee and hip flexion, knee valgus and hip internal rotation, ankle rotation, knee and hip displacement, and stance width (55). The LESS-RT was created to allow for real-time screening sessions to provide reliable measures of landing biomechanics that can detect risks associated with noncontact lower extremity injuries (55).

The LESS-RT is a valid and reliable clinical assessment tool to detect poor-landing biomechanics associated with ACL and other lower extremity injuries (59). Padua et al. determined the original LESS reliability intraclass correlation coefficient (ICC) to be 0.84 and the standard error of measurement (SEM) to be 0.71 (56). The LESS-RT revealed interrater reliability and precision to be comparable with ICC ranging from 0.72- 0.81 and the SEM ranging from 0.69- 0.79 (55).

The LESS-RT analyzes risk factors caused by poor knee flexion and increased knee valgus. A limited amount of knee and hip displacement and knee valgus leads to a “stiff” landing posture with less sagittal-plane displacement (23). Most landing assessments focus only on the hip and knee, yet the ankle plays the largest role in the absorption of landing forces (30). Ankle, knee, and hip joint muscles assist each other in controlling jump landing to assist with a soft landing (30). The ankle plantar flexors and knee extensors are responsible for reducing the body’s kinetic energy upon landing (30). Minimal DROM upon landing results in greater ground reaction landing forces and reduced knee and hip flexion displacement in the sagittal plane (30). These factors are associated with greater knee-valgus displacement. Studies restricting ankle-DROM result in greater knee-valgus displacement effecting the frontal plane motion (12, 34). Fong et al. determined individuals with poor DROM exhibited greater ground reaction forces and decreased knee-flexion displacement (30). These findings are consisted with the study by Kovacs et al. that determined heal-toe foot placement is associated with less sagittal-plane displacement at the ankle, knee, and hip (43). A heel-toe landing would be associated with a stiff landing and less shock absorption, increasing force on the lower extremities and leading to a potential injury (43). These modifiable risks, associated with lower extremity injuries, are vital to inform recreational athletes of the potential injuries that could occur.

The Weight Bearing Lunge Test (WBLT). Clinicians have measured DROM with photography, electric goniometers, rulers, and inclinometers; however, these are time-consuming and have rater variability (13). The weight-bearing assessment of ankle-DROM, also known as the WBLT, is a quick, real time assessment with limited equipment needed. This test requires the subject to touch their knee to the wall, while keeping the heel firmly planted. The novelty of the WBLT is that it assesses athletes DROM while weight bearing rather than most assessments which measure this range of motion in an open chain (13). Dorsiflexion is determined as the greatest distance the foot can move away from the wall, while keeping the heel planted and knee touching the wall during a lunging action. The measurement from the great toe to the wall is the calculated distance in centimeters (37). Previous evidence determined good inter-rater reliability (ICC= .80-.99) and intra-rater reliability (ICC= .65-.99) with the minimal detectable change (MDC) of 1.6 cm and 1.9 cm, respectively (57).

The LESS-RT and WBLT evaluates risk factors most associated with common lower extremity injuries seen in the collegiate recreation athletic population. Previous research utilizing 3D motion analysis laboratory assessments determined the relationship between DROM and jump landing, however there is a need for field measures of lower extremity functionality. This would aid in being able to provide recreational athletes with the knowledge of injury risk and have a resource for prevention and rehabilitation programs to decrease their injury risk, thus allowing them to continue to reap the benefits of recreational PA. Because there is limited research on recreational athletes, additional data and knowledge will aid in future research on recreational athletes participating in recreational sports.

CHAPTER 3

METHODOLOGY

STUDY DESIGN

A cross-sectional study design was used to determine the relationship between ankle DROM and LESS-RT scores in individuals who participate in club soccer or basketball. The dependent variables were LESS-RT and WBLT scores. The Old Dominion University Institutional Review Board (IRB) approved all research procedures. All subjects reviewed and signed an IRB approved informed consent prior to participation.

PARTICIPANTS

Thirty-six subjects participated: sport club-soccer (women, n = 15), men, n = 11)) and sport club-basketball (women, n = 10). Demographic information including age, height, weight, years in sport, and class standing can be found in Table 1.

To be included, subjects had to be recreational athletes between the ages of 18 and 25 years, participating in collegiate recreational club or intramural soccer or basketball, not currently injured and able to perform weight bearing activities. Recruitment included university announcements, flyers, and sport team presentations.

PROCEDURES

Participants completed all testing in a single testing session. After the subjects provided written informed consent, the subjects completed a demographic questionnaire which assessed their orthopedic injury history and PA level. After completion of the questionnaire, subjects completed the WBLT on each limb and the LESS-RT. The order of the WBLT and LESS-RT completion was not randomized or counterbalanced; however, through the course of mass screening sessions the order varied across subjects. All LESS-RT assessments were conducted by an exercise physiologist investigator who had no prior experience with landing biomechanical assessment. All WBLT measures were completed by athletic trainers with 2-10 years of experience.

INSTRUMENTATION

Demographic Questionnaire. The demographic questionnaire was used to collect basic demographic information to include: gender, race, ethnicity, height, age, and weight. In addition, the questionnaire assessed their level of PA (i.e. recreational athlete, collegiate athlete, performing arts, exercise for fitness, occupation, or sedentary) and class standing. The subjects recorded years of participation in their primary recreational sport PA, as well as years of participation at a collegiate level. Finally, the demographic questionnaire was used to assess the subject's previous injury history. The injury history questionnaire evaluated sport injuries to the lower extremity (back, knee, hip, ankle, and foot) in addition to concussion history. The subjects were also asked to provide their time to return to play and the perception of the severity of their injury (mild, moderate, and severe).

Weight Bearing Lunge Test (WBLT). The WBLT was used as a functional assessment of ankle DROM. The technique was performed as previously described (13, 63). The participant was placed standing, facing a wall with the test foot positioned perpendicular to the wall, the second toe at the 4cm mark on the tape measure, and the midline of the heel placed directly on a piece of tape on the floor. The participants were then instructed to lunge forward, directing their knee toward the wall until they reached maximum ankle DROM. Maximal DROM was defined as the point right before the heel lifts off the ground. If the knee made contact with the wall and the heel remained on the ground, the foot was repositioned in 1cm increments away from the wall until maximal DROM was achieved. The rater then recorded the distance from the wall to the big toe in centimeters. The test was performed two times on each limb, one practice trial and one test trial. Previous evidence has been summarized regarding the reliability of this measure. The WBLT has good interrater reliability (ICC= 0.80-0.99) and intrarater reliability (ICC= 0.65-0.99) with the minimal detectable change (MDC) of 1.6 cm and 1.9 cm, respectively (57).

WBLT scores for each limb were summed together to determine a total DROM score (WBLT-Total) which was used for data analysis. Additional exploratory analysis included using the asymmetrical difference between scores as the dependent variable. The asymmetrical difference is the absolute difference between WBLT-Left and WBLT-Right scores (WBLT-Symmetry).

Landing Error Scoring System Real Time (LESS-RT). The LESS-RT was used to assess landing mechanics and risk for lower extremity injury through frontal and sagittal plane real time motion analysis, as described by Padua et al. (55). The participants were instructed to stand on a 30 cm box, toes facing forward at the front edge of the box. The rater measured 50% of their height and placed a target line mark on the floor for the subject to jump towards. The participants were then instructed to jump forward to the mark, and upon landing, immediately perform a vertical jump for maximum height. Subjects did not receive feedback or coaching on jumping or landing techniques during the testing session. Participants were given 2 practice trails to perform the task successfully prior to completing the 4 test trials. A successful jump was characterized by 1) both feet simultaneously leaving the box, 2) the participant jumped forward off the box without vertical motion after takeoff from the box, 3) the participant was able to jump and land on the target line 4) the participant completed a vertical jump immediately after landing, 5) the participant was able to complete the landing and vertical jump in a fluid motion without pause after making initial contact with the ground (55). The scores of 10 landing characteristics were summed to determine the subject's total LESS-RT score for data analysis. The rater observed the following characteristics in the frontal plane: stance width, maximum food-rotation position, initial foot contact, maximum knee-valgus angle, and amount of lateral flexion. The following items were observed in the sagittal plane: initial landing of feet, amount of knee-flexion displacement, amount of trunk-flexion displacement, total joint displacement in the sagittal plane. Finally, an overall impression item was observed and scored.

Literature revealed good LESS-RT interrater reliability (ICC range = 0.69- 0.81) and precision (SEM range = 0.69- 0.79)(55). The LESS-RT total score range is from 0-15; higher scores indicated poor landing mechanics and increased risk of injury (55).

STATISTICAL ANALYSIS

All statistical analyses were performed in SPSS Software Version 22.0 (SPSS Inc., Chicago, IL). Descriptive statistics (mean ± standard deviation or median (interquartile range, IQR)) were calculated for demographic and outcome variables. Due to the non-normal distribution of the data, Spearman rank correlation coefficients were calculated to examine the relationship between the LESS-RT and WBLT-Total scores. R-values were interpreted as very strong (0.8- 1.0), strong (0.6- 0.8), moderate (0.4 - 0.6), weak (0.2 - 0.4), or no relationship (0.0 - 0.2). Alpha was set a priori $p<0.05$.

Table 1. Demographic mean and standard deviation measures for the total subject population and individual sport club team.

Team	N	Height (cm) *M± SD*	Weight (kg) *M±SD*	Age (yrs.) *M±SD*	Years Participation (yrs.) *M±SD*
Total	36	168.59±10.93	71.18±13.25	20.39±1.69	12.56±4.42
WSOC	15	163.49±4.81	63.36±9.97	20.27±1.62	12.67±4.73
MSOC	11	178.03±13.98	82.27±11.56	21.55±1.63	13.82±4.92
WBB	10	165.86±5.87	70.68±11.29	19.3±1.06	11.00±3.13

*Note: M=mean, SD=standard deviation, WSOC=women's soccer club participants, MSOC=men's soccer club team participants, WBB=women's basketball club participant

CHAPTER 4

RESULTS

DESCRIPTIVE ANALYSIS

Descriptive analysis of injury history for all subjects is presented in Table 2. A total of 78 previous injuries were reported for all participants with 42% of these injuries to the ankle and foot (n=33), 14% shin splints (n=11), and 23% knee injury (n=18). In total, 11% (n=9) of reported injuries were concussions. The highest reported orthopedic injury was sprains to the lower extremity. Foot and ankle ligament sprains were the highest reported injury with a total of 21 injuries: 11 (52%) in women's soccer subjects (WSOC), 2 (9%) in men's soccer subjects (MSOC), and 8 (38%) in women's basketball subjects (WBB). Knee ligament sprains accounted for 9 total injuries reported with the highest reported by those participating in WBB (n=4, 44%). Muscle strains at the hip or knee accounted for 5 injuries, with the highest number reported by WSOC (n=3). A summary of additional orthopedic injury information can be found in Table 2.

WEIGHT BEARING LUNGE

For the total group (n=36), median (IQR) range for the WBLT are as follows: WBLT-Left = 9.0(3.34cm), WBLT-Right = 9.1(3.88cm), WBLT-Symmetry = 1.15(2.38cm), and WBLT-Total = 18(6.88cm). The WBB participants had the greatest total DROM 19.25(10.13cm) and least asymmetry (WMLT-Symmetry = 0.75(1.13cm)) compared to WSOC and MSOC. The median (IQR) for individual sport WBLT scores are presented in Table 3.

LANDING ERROR SCORING SYSTEM

Total overall LESS-RT median (IQR) score was 4.5(6.0). The WSOC subjects median score was 5.0(7.0), WBB subjects was 5.5(3.25) and MSOC was 1.0(5.0). The median (IQR) scores for each individual LESS-RT item can be found in Table 4. Of the 10 items, amount of knee-flexion displacement, amount of trunk-flexion displacement and total-joint displacement in the sagittal plane had the greatest scored errors amongst all individual items. MSOC participants scored fewer errors in all categories compared to both women's teams, with the most errors scored in WBB participants; particularly in knee-flexion displacement, trunk-flexion displacement, and overall impression.

OUTCOME VARIABLE RELATIONSHIP

A weak, insignificant relationship was found between WBLT-Total score and LESS-RT total score ($r = 0.11$, $p = 0.52$). There was no significant relationship found between WBLT-Symmetry score and LESS-RT total ($r = -0.04$, $p = 0.79$). A weak, insignificant relationship was found between WBLT-Total and LESS-RT foot position ($r = 0.27$, $p = 0.12$) and LESS-RT trunk flexion ($r = 0.24$, $p = 0.12$), with no other relationships found between LESS-RT items and WBLT score (additional correlations found in Table 5).

Table 2. Descriptive analysis of orthopedic injury history.

Team	Concussion	Back Injury	Knee/Hip				Lower Leg		Foot/Ankle			
			Ligament Sprain	Muscle Strain	Fracture	Dislocation/ Surgery	Shin Splint	Fracture	Ligament Sprain	Muscle Strain	Fracture	Dislocation/ Surgery
Total	9	4	9	5	1	3	11	3	21	5	6	1
WSOC	6	0	2	3	0	0	4	2	11	2	3	1
MSOC	3	1	3	1	1	1	3	1	2	0	1	0
WBB	0	3	4	1	0	2	4	0	8	3	2	0

*Note: WSOC=women’s soccer club participants, MSOC=men’s soccer club team participants, WBB=women’s basketball club participant

Table 3. Median and interquartile range (IQR) for Weight Bearing Lunge Test (WBLT) scores (cm) for the total group and individual teams

Team	WBLT-Left	WBLT-Right	WBLT-Symmetry	WBLT-Total
Total	9.1(3.9)	9.0(3.4)	1.2(2.4)	18.8(6.9)
WSOC	8.6(3.5)	9.8(3.8)	1.2(3.0)	18.5(6.7)
MSOC	10.0(4.5)	8.9(2.5)	1.5(2.7)	18.9(6.5)
WBB	9.8(5.2)	9.0(5.1)	0.8(1.1)	19.3(10.1)

*Note: WSOC=women's soccer club participants, MSOC=men's soccer club team participants, WBB=women's basketball club participant, WBLT =weight bearing lunge test

Table 4. Median (interquartile range (IQR)) of Landing Error Scoring System-Real Time (LESS-RT) total and individual characteristic scoring items.

Team	LESS-RT Total	LESS-RT individual scoring items									
		SW	MFP	IFC	MKV	ALTF	ILF	AKFD	ATFD	TJD	OI
Total	4.5(6.0)	1.0(1.0)	0.0(0.0)	+	0.0(1.0)	0.0(0.0)	+	1.0(1.0)	1.0(1.0)	1.0(1.0)	1.0(1.0)
WSOC	5.0(7.0)	1.0(1.0)	0.0(0.0)	+	0.0(1.0)	0.0(0.0)	+	1.0(1.0)	1.0(2.0)	1.0(1.0)	1.0(1.0)
MSOC	1.0(5.0)	0.0(1.0)	0.0(0.0)	+	0.0(0.0)	0.0(0.0)	+	0.0(2.0)	0.0(1.0)	0.0(1.0)	0.0(1.0)
WBB	5.5(3.3)	0.5(1.0)	0.0(1.0)	+	0.5(1.0)	0.0(0.0)	+	1.0(0.5)	1.0(0.5)	1.0(0.25)	0.0(0.0)

Note: LESS-RT Total= Landing Error Scoring System-Real Time Total score, SW=stance width, MFP=maximum foot position, IFC= initial foot contact, MKV=maximum knee valgus, ALTF=amount of lateral trunk flexion, ILF=initial landing of feet, AKFD=amount of knee flexion displacement, ATFD=amount of trunk flexion displacement, TJD=total joint displacement, OI=overall impression, (+) indicates no errors were scored in these individual items

Table 5. Correlations for Landing Error Scoring System-Real Time (LESS-RT) individual items and WBLT-Total score and WBLT-Symmetry score for all participants

LESS-RT items	WBLT-Total		WBLT-Symmetry	
	r	*P value*	*r*	*P value*
SW	0.10	0.58	-0.14	0.42
MFP	0.27	0.11	0.13	0.44
MKV	-0.19	0.28	-0.14	0.40
ALTF	0.14	0.42	0.14	0.42
AKFD	-0.01	0.97	-0.004	0.99
ATFD	0.24	0.16	-0.004	0.80
TJD	0.10	0.55	-0.10	0.56
OI	0.01	0.95	-0.14	0.43

*Note: LESS-RT= Landing Error Scoring System-Real Time, SW=stance width, MFP=maximum foot position, MKV=maximum knee valgus, ALTF=amount of lateral trunk flexion, AKFD=amount of knee flexion displacement, ATFD=amount of trunk flexion displacement, TJD=total joint displacement, OI=overall impression

CHAPTER 5

DISCUSSION

OVERVIEW OF FINDINGS

The primary purpose of this study was to determine the relationship between LESS-RT total score and DROM. It was hypothesized that there would be a moderate, significant relationship between LESS-RT and WBLT-Total score in recreational athletes. Our findings indicate there is a weak relationship between LESS-RT total score and WBLT-Total ($r = 0.11$, $p = 0.52$) and WBLT-Symmetry score ($r = -0.04$, $p = 0.79$). In addition, none of the relationships between the WBLT scores and individual LESS-RT items were significant.

INJURY DEMOGRAPHIC

There were a total of 78 injuries reported by the participants. A majority of WSOC and MSOC reported their most recent injury was >1-5 years ago, compared to WBB reporting the majority of injuries >6 weeks to one year ago. Consistent with current literature (38), our results indicated the most commonly injured joint region of the body was the foot/ankle (n=33/78, 42.3%), followed by shin splints (n = 11, 14.0%) and concussions (n = 9, 11.5%). WSOC reported the highest number of foot and ankle sprains (n = 11), followed by WBB (n = 8). Current injury distribution is similar to that previously reported with ankle sprains representing more than two thirds of all lower extremity injuries in soccer and basketball (25). The literature has also reported adult female soccer players have a higher rate of ankle sprains of 43.4% compared to males 37.43%; which is consistent with our data where the WSOC participants reported more sprains at the foot and ankle than the MSOC participants (51).

Shin splints were the second highest number of injuries accounting for approximately 14% of all injuries reported. Interestingly of all shin splints, WSOC and WBB reported equal number of injuries 36.4% (n=4/11) where MSOC reported 27.27% (n=3/11). A study of 150 Division III female soccer players found consistent data with 72% of the players reporting history of shin splints (16). Additional lower extremity injuries reported were knee sprains with WBB having the highest percentage (n=4/9, 44.4%) followed by MSOC (n=3/9, 33.3%). However, WSOC reported the highest percentage of knee strains (n=3/5, 60%) compared to both WBB and MSOC. Similar to a study that included basketball and soccer athletes from professional, intramural, collegiate, and recreational levels; female basketball players were found to have a higher instance of knee sprain/strains compared to female soccer players (21). Women's basketball and soccer athletes reported a higher instance of ACL injuries compared to men's teams in previous literature (38). Thus indicating the need for women's focused prevention programs focused on the ankle and knee.

In addition to lower extremity injuries, concussions are a common injury associated with soccer athletes. Our results indicated a total of 9 concussions accounting for 11.53% of total injuries. Consistent with literature, WSOC reported the highest percentage 66% (n=6/9) followed by MSOC 33% (n=3/9). Due to the nature of soccer, collisions between players increases the incidence of concussions (20). Concussions are the third leading injury of NCAA female soccer players, leading to an average of 10 days away from PA (25). As suggested by Covassin et al.(20), female basketball and soccer players experience more concussions than male basketball and soccer players in competition. Literature suggests that a significantly greater concussion rate in female soccer may be due to a greater ball-to-head ratio and weak neck muscles (10).

RESEARCH IMPLICATIONS

Our study found median (IQR) WBLT-Total for the total group to be 18(6.9cm). The WBB participants had the most DROM with WBLT-Total 19.3(10.1 cm), followed by MSOC

(18.9(6.5 cm)) and WSOC (18.5(6.7 cm)). In addition, the average score for the right and left limbs of all participants was 8.8 and 8.5 cm, respectively. These results are lower compared to previous literature which stated normative WBLT measures for right limb was 12.0 cm and 11.9 cm for the left limb (36). Hoch et al.(36) determined normative values for limb symmetry differences in a healthy population of $\leq$1.5 cm. The subjects included in this study displayed median symmetries of 1.0-2.1cm. Asymmetrical differences in range of motion may be important as differences lead to increased ground reaction force on the initial landing limb denoting an increased risk of lower extremity injury (54, 61).

Previous research has examined the LESS-RT in intramural, sport club, and NCAA-Division I athletes (62). Although not significantly different the results reported LESS-Total scores for intramural subjects as 5.39 ± 0.29, sport club subjects as 5.26 ± 0.27, and NCAA division 1 athletes as 5.06 ± 0.28. Additional research determined the reliability of the LESS-RT mean total scores for all participants ranging from 4.9-6.2 (55). For the purposes of this investigation, we utilized the LESS-RT with an average score (± standard deviation) as 4.5 ± 6.0 indicating few errors and good landing mechanics. A lower score on the LESS-RT indicates better landing mechanics and a decreased risk of lower extremity injury. Furthermore, mean LESS-RT scores were higher for women compared to male participants indicating that women had poorer landing mechanics. This finding is consistent with literature which also reported that women (5.34 ± 2.76) had more errors on the LESS when compared to men (4.65 ±1.6) (14). Higher scores in specific LESS-RT items with women has been suggested to contribute to lower extremity injury, specifically ACL injury (55). The underlying factors which may be contributing to ACL injury are thought to be poor hip muscle strength, increased anterior directed sheer force, and increased internal rotation of the knee (66).

Five factors have been identified to contribute the most to poor LESS scores utilizing the original LESS methodology (14). Females scored errors in knee flexion, hip flexion, knee valgus, wide stance width, and total joint flexion displacement (14). Males were found to have poor landing due to externally rotated feet positioning, heel first initial landing, and asymmetrical foot contact (14). While we used the LESS-RT, our results are consistent with previous research as WSOC and WBB scored more errors in stance width, knee-valgus angle, knee-flexion displacement, trunk-flexion displacement, and total joint displacement in the sagittal plane (Table 4). In addition, overall impressions for both women's teams indicate a higher mean score compared to the men's score. Thus, the men's team exhibited a "softer" landing which has been attributed to absorbing more landing force and associated with having less ground reaction forces (55).

In this study, both women's teams had more knee valgus errors compared to the men's team. Knee valgus in landing mechanics has been determined as one of the leading causes of ACL injury (2). Women consistently have greater knee valgus compared to men in all levels of sport participation, indicating altered motor control and thus increasing the anterior sheer force upon landing (18, 19, 31). Additionally, females measured higher knee flexion joint angles compared to males in a stop-jump landing task (18). This data suggest poor knee flexion displacement can cause an increased ACL load and increased lower-extremity joint forces (18). Decreased sagittal flexion angles at the trunk, hip, and knee are also associated with poor female landing mechanics, placing females at a 5.3 times higher risk of sustaining a knee valgus collapse (14, 44). Using the LESS-RT, our results indicated more errors in knee flexion, hip flexion, and total joint displacement in WSOC and WBB LESS-RT scores compared to MSOC scores. The errors in these individual items indicate poor sagittal plane flexion which leads to a "stiff" landing posture (23). Our results indicated WBB to have the highest errors scored in LESS-RT knee flexion, hip flexion, and total joint displacement compared to WSOC and MSOC. Another frequent error scored in the women's group was an overall impression error which was scored as: excellent (no error- soft landing with no valgus), average (1 error- any landing between 0-2 with minimal valgus, differences in knee and trunk flexion, etc.), and poor (2 error- stiff landing and large valgus, or only large valgus). Previous literature has found collegiate female basketball players to demonstrate less knee flexion upon landing causing a more erect posture (stiff) and a greater risk of injury (52). LESS-RT reported scores are validated by the literature indicating the LESS total, knee flexion, trunk flexion, joint displacement, and overall impression values to be representative of the gender differences within the recreational athletic population.

Minimal energy dissipation at the ankle is associated with decreased DROM and decreased sagittal-plane displacement creating a more erect (stiff) landing posture (23, 30). Greater DROM has been associated with greater knee-flexion and smaller ground reaction forces, indicating decreased DROM may be a risk factor for lower extremity injury (30). If the WBLT and LESS-RT scores were correlated, we may not have to include both measures in an injury screen. However, no relationship was found between WBLT-Total score or WBLT-Symmetry score and LESS-RT scores. Conversely, Fong et al. (30) determined ankle-dorsiflexion ROM (extended-knee) was significantly correlated to knee displacement, vertical ground reaction force, and posterior ground reaction force. Greater passive ankle-DROM was associated with smaller ground reaction forces during landing, indicating a "soft" landing (30). Although Fong et al. (30), did not find a significant correlation between flexed-knee DROM and knee flexion displacement and ground reaction force, statistical trends were reported for these variables. Hagins et al. (34) evaluated the effects of limited DROM on landing mechanics and found reduced DROM was associated with greater knee-valgus displacement and ground reaction forces. However, we identified no relationship between DROM and knee valgus displacement. This may be due to the limited number of subjects that had errors on this task in the LESS-RT as 8.3% scored errors for large knee valgus and 31% scored an error of small knee valgus with the majority scoring no valgus error.

RESEARCH LIMITATIONS

This study is not without limitations. First, this study included a small number of subjects which were a majority female (70%) and only participated in recreational club soccer and basketball. Future research should consider a larger sample size including an equal number of males and females and subjects participating in other recreation sports. Injury history was collected retrospectively through self-report; therefore, it is unknown how accurate the injury history information was reported. There are numerous methods to measure DROM and jump landing mechanics and we utilized two measures that could be collected with minimal equipment and in real time. Future research may consider adding additional measures of DROM assessment or landing mechanics. Another consideration, is utilizing specific measurements for certain sports focused on sport-specific tasks. Finally, the researcher scoring the LESS-RT was a novice exercise physiologist. While the rater completed a two-hour training session and scored practice sessions, future research should be performed to examine the interrater reliability of this measure between novice and experienced raters.

CONCLUSION

We reject our hypothesis, there is no relationship between the LESS-RT and WBLT. Although no relationship was found between these variables, errors on the LESS-RT and deficits in DROM were measured. The LESS-RT and WBLT should be considered in future research studies when examining injury risk in physically active populations.

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CURRICULUM VITAE

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Education:

Old Dominion University, Norfolk Virginia August 2016
Master of Science in Exercise Science)
Thesis "The Relationship between Landing Error Scoring System-Real Time and Dorsiflexion Range of Motion in Recreational Athletes."

University of North Carolina Wilmington, Wilmington North Carolina May 2014
Bachelor of Art in Exercise Science; Minor: Psychology

Professional Experience

Old Dominion University, Norfolk Virginia August 2014- Present
Graduate Assistant of Fitness and Wellness

- Aid in planning and implementing fitness and wellness classes, programs, and events in representation of the University Recreation and Wellness Department
- Manage and train fitness staff on fitness assessments, daily duties, and exercise-related
- Manage University Village Fitness Center, a satellite recreation center
- Partner with university departments, local business, leaning communities, and academic courses for collaboration for programs for members to increase engagement and retention

YMCA of South Hampton Roads, Norfolk Virginia December 2014-Present
Transitions Coach, Personal Trainer

- Develop exercise training program for post-physical therapy patients

Presentations

NIRSA Southeast Fitness Expo, University of North Carolina Asheville, Asheville North Carolina

- "Get your Fitness on Trax, how to Utilize an Online Exercise Tool (Activtrax) in a University Recreation Center"
- "Bigger is not Always Better, A Guide to Fitness and Wellness Programming Outside the 'Traditional' Border"

Professional Memberships

NIRSA Student Member Network, ACSM, AFAA, NETA, Yoga Alliance