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Identification of Factors Contributing to Musculoskeletal Injuries in Military Basic Trainees

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IDENTIFICATION OF FACTORS CONTRIBUTING TO MUSCULOSKELETAL INJURIES IN MILITARY BASIC TRAINEES

by

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DEDICATION

To my husband, for his support of my dreams. To my mother, who taught me to serve. And to my father, who not only taught me, but made me believe, that I could do anything.

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ABSTRACT

Due to the physical activity requirements of the United States (U.S.) Armed Forces, there is a concerning incidence rate of musculoskeletal injuries in military personnel. In the basic trainee population specifically, multiple studies have reported a range of exercise-related injury incidence from 14% to 42% in males and 27% to 61.7% in females. Depending on the severity, these injuries can exclude basic trainees from participation, ultimately altering career trajectory and creating the possibility of long-term disability. The studies of this dissertation examine variations in muscle strength, flexibility, and dynamic postural control as a means to identify those basic trainees with increased odds of reporting a back or lower extremity musculoskeletal injury during U.S. Army Basic Combat Training (BCT).

The Star Excursion Balance Test (SEBT) is used in clinical and research settings to assess dynamic postural control. Moderate to excellent intra-rater, inter-rater, and test-retest reliabilities of measures obtained from the SEBT have been published; however, current testing procedures are not time efficient for large-scale application. The first study of this dissertation determined the inter-rater and test-retest reliabilities of the shortened testing version of the SEBT—the Quick Star Excursion Balance Test (QSEBT). Forty-six healthy participants (21 males, 25 females; age = 23.5 ± 4.3 years; height = 170.6 ± 8.3 cm; mass = 72.7 ± 15.4 kg) were evaluated by 2 examiners simultaneously in the performance of 8 tasks of the QSEBT bilaterally, followed by repeating the test to assess test-retest reliability. Intraclass correlation coefficients (ICC) for inter-rater comparisons

of the QSEBT for all 8 reach directions ranged from 0.83 to 0.98 for both stance legs. ICCs for test-retest reliability of the QSEBT ranged from 0.64 to 0.88 bilaterally. It was concluded that measures obtained from the QSEBT have moderate to excellent reliability for novice examiners when they are instructed on how to administer the test and provided with oral instructions to read to participants. Researchers and clinicians can use the QSEBT to assess dynamic postural control by recording measurements in real-time.

The second study of this dissertation examined the predictive validity between individual and combinations of measures in the reporting of a back or lower extremity musculoskeletal injury to a medical provider during U.S. Army BCT. Four hundred and twenty-seven participants (141 females, 286 males; age: 21.43 ± 3.61 years; height: 171.63 ± 9.37 cm; mass: 73.55 ± 13.29 kg) completed baseline survey questionnaires, body composition testing, and baseline physical performance measures (QSEBT, Weight-Bearing Lunge Test (WBLT), and Single Leg Wall Squat (SLWS)) and participated in self-report of injury questionnaires throughout BCT. Ultimately, 147 participants reported at least one injury during training. Multiple logistic regression was applied to assess the relationship between the measures taken prior to beginning BCT and the report of musculoskeletal injury. We estimate each centimeter increase in the reach distance of the 3-direction composite QSEBT score (dominant stance leg) is associated with a 2.1% reduction (OR = 0.979, 95% CI [0.958, 1.001], p = 0.06) in the odds of a basic trainee in reporting an injury during BCT, after adjusting for sex, bone mineral density, and the average days of 30 minutes of exercise per week in the two months prior to BCT. The measures obtained on the WBLT and SLWS did not contribute to the final model. Dynamic postural control assessments may contribute to identifying basic trainees at an increased

odds of injury during BCT. Future study should examine the predictive validity of the physical performance tests on diagnosed musculoskeletal injury from a medical provider, as well as lost time and attrition from training.

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LIST OF ABBREVIATIONS

ACSM .... American College of Sports Medicine

AHA .... American Heart Association

BCT .... Basic Combat Training

BMC .... bone mineral content

BMD .... bone mineral density

BMI .... Body Mass Index

CI .... confidence interval

cm .... centimeter

CSA .... cross-sectional area

DEXA .... dual-energy x-ray absorptiometry

DMPA .... depo-medroxyprogesterone acetate

EDI .... Garner's Eating Disorder Inventory

FNSI .... femoral neck stress injury

ICC .... intraclass correlation coefficient

IST .... Initial Strength Test

MDC .... minimal detectable change

mg .... milligram

MLE .... maximum likelihood estimation

mm .... millimeter

PAR-Q .... Physical Activity Readiness Questionnaire

p-yrs .... person-years

QSEBT .... Quick Star Excursion Balance Test

RCT .... randomized controlled trial

ROC .... receiver operating characteristic

RR .... relative risk

SC .... South Carolina

SD .... standard deviation

SEBT .... Star Excursion Balance Test

SEM .... standard error of the measurement

SLWS .... Single Leg Wall Squat

TBBMC .... total body bone mineral content

U.S. .... United States

USARIEM .... United States Army Research Institute of Environmental Medicine

USMA .... United States Military Academy

WBLT .... Weight-Bearing Lunge Test

CHAPTER 1

OVERALL INTRODUCTION

Due to the physical activity requirements of the United States (U.S.) Armed Forces, musculoskeletal injuries historically have been, and still are, occurring to military personnel at a concerning rate. In 2006, 743,547 injury-related musculoskeletal conditions were documented among active duty non-deployed service members across the 4 branches of the Armed Forces. Of these injuries, 82.3% were evaluated as overuse injuries, with 41.8% and 34.7% of those injuries documented to the lower extremity and vertebral column, respectively.[1] In the basic trainee population, a variety of studies have reported exercise-related injury incidence from 14% to 42% in males and 27% to 61.7% in females.[2-5] A study specific to the U.S. Army reported the most commonly diagnosed injuries for a male basic trainee as low back pain (7.3%) and tendinitis (6.5%), resulting in limited duty of 10 days per 100 person-weeks. For the female basic trainee, strains (15.6%) and stress fractures (12.3%) were the most commonly diagnosed injuries, resulting in limited duty of 32 days per 100 person-weeks.[2]

Due to the financial costs and possibility of long-term disability, stress fracture incidence is especially a concern. Stress fracture incidence rates are particularly high in the basic trainee population, with up to 12.3% of females[3] and 6.1% of males[6] experiencing at least one stress fracture during training. This incidence rate is 14.7 and 56.7 times that of active duty and deployed Soldiers respectively,[7] suggesting bone regeneration is further negatively impacted by the sudden elevated physical activity requirements characteristic

to Basic Combat Training (BCT).[8] Unfortunately, these demands combined with additional risk factors common in the basic trainee—such as poor physical fitness,[6,9-15] decreased muscle strength,[10,12] and menstrual irregularities[9,11-13]—are believed to continue to elevate the probability of developing this injury.

Depending on the stress fracture severity and location, these injuries temporarily or in some cases permanently exclude basic trainees from participation, ultimately altering career trajectory and possibly requiring surgery and causing long-term disability.[2] Best case scenarios include rehabilitation of up to 21 weeks before return to training,[16] which is more than 2 times the length of the U.S. Army's 10-week BCT program. Similar issues occur in the U.S. Marine Corps, where stress fractures result in 53,000 lost training days annually, costing the Department of Defense $16.5 million in medical expenses.[2] Stress fractures have been identified to be the most common predictor of discharge during training in the U.S. Marine Corps;[17] similarly, 60% of females and 40% of males with this injury never complete the requirements to graduate from U.S. Army BCT.[18] These implications raise broader questions about how musculoskeletal injuries may influence overall military readiness.

A primary reason for the high prevalence of musculoskeletal injury and stress fractures among basic trainees is the exposure to elevated levels of repetitive stress required by the BCT program.[2,19] Unfortunately, these demands, coupled with additional risk factors—such as sudden increases in physical activity,[9,11] poor dynamic postural control,[20] and decreased muscle strength[6,21]—are believed, but have not been clearly demonstrated, to increase the likelihood of developing a musculoskeletal injury.[6,14,19,22-25] The way in which these factors interact are likely to contribute to the severity of the injury's

presentation. Congenital or fitness-based factors, including poor range of motion (i.e., ankle dorsiflexion),[26] can affect biomechanics, leading to the improper distribution of forces during activity.[25] The multifaceted interactions of these risk factors can help explain the high incidence of stress fractures and other musculoskeletal injuries observed in basic trainees.[6,19,23]

The majority of interventions to reduce overuse injuries utilized in the military setting are performed using a group-based approach. For example, the implementation of leadership education and injury surveillance over a 2-year period at a U.S. Army BCT base resulted in a decrease of femoral neck stress fracture incidence in both sexes.[27] However, an additional study examining rest from running for one week during BCT found no evidence that it decreases stress fracture injury incidence.[28] Because every Soldier is inherently different in the risk factors they possess, we believe an individualized method to preventing injury is necessary.

Since back and lower extremity musculoskeletal injuries are occurring at a high incidence rate during U.S. Army BCT, identifying risk factors specific to basic trainees and creating a reliable, time-efficient testing battery to evaluate for associated factors will have a valuable impact for clinicians and researchers. Ideally, screening measures evaluated in this study will establish a basic trainee’s likelihood of injury and lead to development of appropriate intervention(s) for the specific risk profile. This dissertation is innovative in that it seeks to identify modifiable risk factors at an individualized level in the traditionally group-based military setting. As a result, we can mitigate loss of function and discomfort in Soldiers, as well as the costs associated with medical care, extended

training time frames, and attrition from BCT due to lower extremity musculoskeletal injury.

This dissertation consists of 3 studies: (1) a clinical review of current literature regarding stress fracture incidence, etiologic factors, and previous prevention efforts in military populations, (2) a reliability study to assess the inter-rater and test-retest reliabilities of alternate testing procedures of the Quick Star Excursion Balance Test (QSEBT), and (3) a prospective cohort study to establish the predictive validity of the QSEBT, the Weight-Bearing Lunge Test (WBLT), and the Single-Leg Wall Squat (SLWS) in the reporting of a back or lower extremity musculoskeletal injury to a medical provider during U.S. Army BCT at Fort Jackson, SC.

Specific Aims, Objectives, and Hypotheses

Aim 1. To develop a reliable and time-efficient test battery to evaluate for the existence of modifiable risk factors for lower extremity musculoskeletal injury in incoming U.S. Army basic trainees.

Objective 1.1. To determine the inter-rater and test-retest reliability of measures obtained from the QSEBT.

Objective 1.2. To determine the time necessary to complete the testing procedures of the QSEBT.

Aim 2. To establish the predictive validity of individual and combinations of known and plausible risk factors in the development of lower extremity musculoskeletal injury in U.S. Army basic trainees participating in BCT at Fort Jackson, SC.

Objective 2.1. To establish the predictive validity of the ability of a basic trainee to hold the SLWS for one minute during the first week of BCT and the development of lower extremity musculoskeletal injury during participation in BCT at Fort Jackson, SC.

Hypothesis 2.1. Basic trainees who are not able to hold the single-leg wall squat for one minute will be at an increased odds of developing lower extremity musculoskeletal injury when compared to those basic trainees who were able to hold the single-leg wall squat for one minute.

Objective 2.2. To establish the predictive validity of ankle dorsiflexion measurements measured by the WBLT during the first week of BCT and the development of lower extremity musculoskeletal injury during participation in BCT at Fort Jackson, SC.

Hypothesis 2.2. Basic trainees measuring less distance from the wall using the WBLT will be at an increased odds of developing lower extremity musculoskeletal injury when compared to those basic trainees who measured farther distances from the wall.

Objective 2.3. To establish the predictive validity of the ability of a basic trainee to balance on one leg while reaching with the other leg for distance using the QSEBT during the first week of BCT and the development of lower extremity musculoskeletal injury during participation in BCT at Fort Jackson, SC.

Hypothesis 2.3. Basic trainees reaching for shorter distances on the QSEBT after normalizing to leg length will be at an increased odds of developing

lower extremity musculoskeletal injury when compared to those basic trainees who reached for a farther distances.

Assumptions

1. Participants were honest in their self-report responses.
2. Participants exerted maximum effort during the QSEBT, WBLT, and SLWS.
3. Participants were representative of the population of basic trainees who go through BCT at Fort Jackson, SC.
4. Participants were exposed to the same demands associated with BCT.

Delimitations

1. Participants only participated in BCT at Fort Jackson, SC.
2. Injuries were self-reported on a weekly basis.

Limitations

1. Participants may not have been exposed to the same demands associated with BCT.
2. Results may not apply to basic trainees participating in U.S. Army BCT in other locations.
3. Due to the self-report nature of injuries, it is possible that injuries reported to a medical provider were not collected by research staff.

CHAPTER 2

MILITARY TRAINING-RELATED STRESS FRACTURES: A REVIEW AND RECOMMENDATION FOR FURTHER STUDY[1]

ABSTRACT

Context: The growing prevalence of lower extremity stress fractures among United States Armed Forces basic trainees remains a key health and economic concern. Effective prevention and rehabilitation of this condition have been limited by inadequate knowledge of its etiologic factors as well as the lack of consensus in the clinical definition of bone stress injuries in the military population.

Evidence Acquisition: An internet search utilizing PubMed-Medline and Google Scholar was performed to identify recent literature examining stress fractures in military populations. Key words and phrases included: stress fracture, military, diagnosis, treatment, rehabilitation, recovery, and prevention. Reference lists from relevant studies were reviewed to identify any additional studies that were not previously detected in the internet search.

Study Design: Clinical review.

Level of Evidence: Level 3.

Results: Recent studies suggest that in addition to sudden increases in physical activity, other factors such as deficits in bone density, inadequate baseline lower extremity muscle

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[1] Hand AF. To be submitted to *Sports Health*.

strength, and negative energy balance associated with nutritional concerns and activity-induced menstrual abnormalities, may interact to further increase the likelihood of developing a lower extremity stress fracture. Encouragingly, prevention efforts such as leadership education, prevention enforcement, and injury surveillance may be effective in decreasing bone stress injury rates.

Conclusion: By describing recent literature and identifying key risk factors and gaps in knowledge, this information will inform clinicians' prevention efforts and assist the development of future research protocols for the prevention of lower extremity stress fractures. Future research must address how to effectively assess for the presence of modifiable factors and effectively apply prevention efforts to a large population of military basic trainees.

Keywords: military, bone stress injuries, prevention, risk factors

INTRODUCTION

Bone injuries associated with repetitive loads—commonly referred to as stress fractures—occur when bony structures are not able to make the necessary physiologic adjustments in response to these loads.[8] These fractures are relatively uncommon in the general civilian population but are significant concern among basic trainees of the U.S. Armed Forces, who expose their lower extremities to high levels of repetitive stress on a daily basis. Depending on severity and location, stress fractures can either temporarily or permanently exclude basic trainees from participating in training, as well as result in acute and long-term medical costs.[2]

The impact of lower extremity stress fractures is illustrated by Claassen et al[7] who examined the frequency of fractures in the U.S. Armed Forces from 2003 to 2012. This study reported the incidence rate of stress fractures in basic trainees to be 39.7 per 1,000 person-years (p-yrs), in comparison to only 2.7 and 0.7 per 1,000 p-yrs in the active and deployed populations, respectively.[7] These findings support the conclusion that bone regeneration is negatively affected by the sudden elevated lower extremity loading demands related to physical activity experienced by basic trainees during training.[8] These incidence rates are especially pervasive in female basic trainees, with up to 19.1% of females,[9] compared to 6.1% of males,[6] experiencing at least one stress fracture during training. It is estimated that among these injured basic trainees, 60% of females and 40% of males ultimately do not complete the requirements to graduate from U.S. Army Basic Combat Training (BCT).[18] In addition to decreased training completion rates, assessments suggest stress fractures in the U.S. Marine Corps result in 53,000 lost training days and cost the Department of Defense approximately $16.5 million annually.[2]

Given the high incidence of stress fractures in the U.S. Armed Forces, and especially the basic trainee population, there is a need to develop programs that are effective for the prevention, early detection, and treatment of this condition. A clear understanding of etiologic factors and previous prevention efforts surrounding this injury are necessary to approach developing these programs. The purpose of this review is to describe and summarize the recent literature and to identify key, potentially modifiable, risk factors and prevention efforts. This information will inform clinicians and assist the development of research protocols for the prevention of lower extremity stress fractures with an ultimate eye toward mitigating the discomfort and loss of function associated with

these injuries, as well as reducing the substantial costs associated with medical care and loss of training.

METHODS

Search Strategy. A broad internet search using PubMed-Medline and Google Scholar was performed to identify current literature that addresses epidemiology, etiology, diagnosis, treatment, and prevention of stress fractures in the military population. Key words and phrases included: stress fracture, military, diagnosis, treatment, rehabilitation, recovery, and prevention. Reference lists from relevant studies were reviewed to identify any additional studies that were not previously detected in the internet search.

Inclusion and Exclusion Criteria. Studies included in this literature review examined incidence rates, risk factors, rehabilitation, and prevention efforts related to stress fracture in military populations. Studies on risk factors, prevention efforts, and rehabilitation in militaries of countries other than the United States were included. Studies excluded were those that measured incidence rates in other countries because differences in training length and protocol would not allow for proper comparison. Non-English language papers were also not included.

Total Number of Studies Included. Three review articles, 16 prospective cohort studies, 5 retrospective cohort studies, and 4 randomized controlled trials met the criteria for this review.

OVERVIEW OF LITERATURE

The Magnitude of the Problem

Injuries are highly prevalent among U.S. Armed Forces personnel. In a surveillance study examining medical encounters of active duty (non-deployed) Soldiers from 2000 to 2006, Jones et al[29] determined that injuries were the most common reason for Soldiers to seek medical treatment and reported over 1.96 million acute or chronic injury-related encounters in 2006.[29] This frequency is more than twice that of the second most common reason to seek medical treatment, with mental disorders attributing to approximately 755,000 encounters.[29] Of the reported injuries, lower extremity overuse conditions, including stress fractures, tendinitis, and other chronic disorders, accounted for the most frequent general injury type, with an almost 900 per 1,000 p-yrs average across all military branches. Even more concerning is the elevated rate occurring in the Army, with over 1,200 lower extremity overuse injuries per 1,000 p-yrs.[29]

Claassen et al[7] investigated incidence rates of all-cause fractures in the U.S. Armed Forces from 2003 to 2012. The fracture rate in basic trainees was 66 per 1,000 p-yrs, in comparison to only 19.4 and 16.5 per 1,000 p-yrs in the active and deployed populations, respectively.[7] Of the 18,773 incident fractures experienced by basic trainees, 11,296 were classified as stress fractures, accounting for 60% of all fractures sustained in this population. This rate is in stark comparison to the 13.7% and 4.3% of fractures classified as stress fractures in active and deployed personnel, respectively.[7] Additional evaluation of sex differences indicated a 2.2-times higher rate of stress fractures occurring in female basic trainees (94.7 per 1,000 p-yrs) compared to males (29.6 per 1,000 p-yrs).[7]

A number of researchers have also examined stress fracture occurrence in a variety of military populations (**Table 2.1**). From these studies, a range of 1.9% to 6.1% stress fracture incidence rate for males and 5.1% to 19.1% rate for females is observed.[6,9,30,31] This difference is even greater than the 2.2-times higher rate of stress fractures occurring in female basic trainees from Claassen's U.S. Armed Forces investigation.[7] With such diverse study components, it is not surprising that stress fracture incidence rates differ across studies. Demands and length of training—which fluctuate across military branches and specialties—can have a considerable effect on bone's ability to regenerate and repair, and ultimately, the rate of stress fractures.[8] Analysis at the level of individual military services may be important to visualize the varying incidence rates occurring across branches, and to guide future efforts focusing on areas of greatest concern.

The elevated occurrence of stress fractures in the basic training population, in contrast to active and deployed Soldiers, may be having adverse impacts beyond what has been investigated and entirely identified. In a study performed to determine factors associated with discharge from the U.S. Marine Corps basic training, medical-related incidents were the most common reason (53.4%) for basic trainees to be released from training.[17] Of the basic trainees who suffered a stress fracture during training, 29.7% were ultimately discharged, making stress fracture injury the most dominant predictor of discharge. By direct comparison, only 9.2% of basic trainees who did not experience a stress fracture were released, indicating that experiencing a stress fracture makes a basic trainee over 3 times more likely to be dismissed from training.[17] These studies do not examine the loss of training time associated with the non-discharged injured basic trainees, which is an important consideration in the assessment of how these injuries may affect

Soldiers' future combat readiness. Observed rehabilitation periods for multiple stress fracture locations, which are directly related to time lost from training, are available in **Table 2.2**. Rehabilitation can take up to 21 weeks,[16] which is more than 2 times the length of the U.S. Army's BCT program.

The prevalence of stress fractures in the basic training population may have substantial negative consequences beyond just the financial cost of acute and long-term medical care. Serious stress fractures, especially those that require surgical intervention, can alter life trajectory, potentially leading to long-term disability and career change. Additionally, with 30% to 60% of basic trainees with stress-fractures never finishing training[17,18] and others losing varying amounts of training time due to rehabilitation, there is a considerable concern and a lingering question as to how this injury affects military readiness.

POTENTIAL ETIOLOGIC FACTORS FOR LOWER LIMB STRESS FRACTURES

The following section addresses currently identified risk factors for stress fractures, along with a discussion of their influence and interaction with other considerations. Risk factors for male and female military personnel determined in individual studies are presented in **Table 2.3**.

Lower Extremity Morphology and Physical Fitness

Bone physiology is strongly influenced by Wolff's Law—the principle that bones respond to the mechanical stressors placed on them by gravity and muscle activity.[32] By

increasing the demands placed on bones during physical activity, these structures will remodel and repair to accommodate those demands.[32] This protective process is likely to occur in individuals whose conditioning and strength levels match the loads being applied during physical activity. In contrast, early fatigue is more common in individuals who have inadequate physical conditioning and muscle strength. Theoretically, with the onset of fatigue, muscles are no longer able to absorb the forces associated with military training, consequently distributing those forces to be absorbed by bone. These elevated loads are believed to adversely affect the bone regeneration and repair process,[8] which can potentially result in an overuse injury.

Several investigators have researched the effect of poor physical conditioning in an individual prior to beginning training programs. Cosman et al[9] assessed incoming cadets at the U.S. Military Academy (USMA) and determined there was increased stress fracture risk in males who participated in less than 7 hours per week of physical activity in the year leading up to entrance into the academy (RR=2.31, CI [1.29, 4.12]).[9] Additionally, other researchers have associated lower self-ratings of "physical fitness" with increased risk of stress fracture.[12,13] A series of prospective cohort designs sampling a variety of military branches reported that basic trainees who developed stress fractures had lower muscle strength,[10,12] less developed thigh musculature,[6] smaller thigh girth,[6,23] and smaller calf girth,[6] as well as slower entry run times, when compared to those individuals who did not develop a stress fracture.[6,10-14] Further, cross-sectional imaging revealed that female[9] and male[6,9] cadets with "narrower bones" (femoral neck diameter: male RR=1.35 each mm, CI [1.01, 1.81], female RR=1.16 each mm, CI [1.01, 1.33]; male tibial BMC: RR=1.11 each 10 mg, CI [1.03, 1.20]; male tibial cortex CSA: RR= 1.12 each 10 mm^2, CI [1.03, 1.23])[9]

were found to display an increased risk for developing a stress fracture, demonstrating the relationship between prior physical conditioning on bone structure and injury prevention. Beck and colleagues[6] assert that the differences seen in fitness, muscle size, and bone size in people of both sexes who sustained one or more lower extremity stress fractures were due to poor physical conditioning prior to beginning the training program. This observation provides insight into the interactions of multiple risk factors on the development of stress injury.[6]

In addition to run times, Step Tests, which require the participant to step up and down a height at a certain cadence for a predetermined amount of time, have traditionally been used in fitness settings to estimate VO_2 max, as well as to give a representation of overall fitness levels. Cowan et al[15] assessed physical fitness by using of a 5-minute Step Test on female Army basic trainees. "Passing" was defined as completing the entire 5 minutes at a cadence of 30 step cycles (up and down) per minute. After comparison of stress fracture rates to Step Test outcomes, it was determined that females who failed the step test experienced a 76% higher incidence of developing a stress fracture during training.[15] Additionally, it is interesting to note that the majority of stress fractures developed across the USMA in a 4-year period occurred in the first 3 months,[9] providing further evidence that good inception physical conditioning is likely to decrease the likelihood of developing a stress fracture.

There is face validity to Beck's theory that appropriate physical conditioning and muscle strength training prior to beginning military training reduces the likelihood of developing a stress injury to bone.[6] By increasing the demands placed on bone with physical activity, bone will remodel and repair to accommodate those demands, possibly

increasing diameter, cortical thickness, and strength. As muscle strength and endurance increase, more activity is required to cause muscle fatigue, allowing more training to occur before elevated forces are distributed to bone.

Energy Availability

Proper nutrition in basic trainees allows for adequate energy sources, as well as calcium and Vitamin D, which are necessary for bone to adapt appropriately to the stresses placed on it. In contrast, poor nutrition may result in a lack of energy availability. Unfortunately, with excessive energy expenditure, such as the demands of BCT, appropriate nutrition can still be inadequate. This phenomenon is referred to as “negative energy balance,” meaning that energy expenditure outweighs energy consumed. Females are at additional risk from inadequate energy availability due to the combined effects of potential disordered eating and altered menstruation as risk factors of poor bone health.[9,33]

Low body weight[30] and body mass index (BMI),[10,30] as well as rapid decreases in body weight associated with physical activity,[23] may also be important etiologic factors in predicting lower extremity stress fractures. Armstrong et al[23] reported that female and male participants who developed a stress fracture during a summer program at the U.S. Naval Academy lost more than 4 times the weight from entry into the program to date of diagnosis than matched controls.[23] Conversely, in a 4-year study performed at the USMA, Cosman and colleagues[9] found no association between weight changes and stress fracture incidence in either sex. However, participants of the Cosman[9] study were typically physically fit individuals admitted to the USMA and may differ in fitness levels from the majority of trainees entering military BCT. Physically fit individuals entering a training program may

not experience the same type of weight loss as other trainees experiencing a major life change associated with the amount of physical activity of BCT.

The effect of nutrients, specifically Vitamin D, calcium, and iron, on stress fracture incidence has further been examined. In a study performed by Lappe et al[11] in female Navy basic trainees, after all participants were exposed to the same training conditions, the intent-to-treat analysis determined a 20% lower incidence of stress fractures in the group taking calcium and vitamin D supplementation.[11] In addition, Yanovich et al[34] displayed an association between anemia and iron deficiency anemia in Soldiers and their potential for bone stress injuries during training. At the end of training, female Soldiers who had sustained a stress fracture displayed a higher rate of anemia (23.1 %) and iron deficiency anemia (23.1%) than those Soldiers who did not sustain a stress fracture (10.0% and 8.3%, respectively).[34] Encouragingly, this difference was even noted at inception—prior to beginning training, female Soldiers who would ultimately sustain a stress fracture displayed a higher prevalence of anemia (28.6%) and iron deficiency anemia (23.6%) compared to those Soldiers who ultimately would not sustain a stress fracture (17.1% and 15.0%).[34]

Female cadets have also displayed an increased risk for developing a stress fracture if less time had elapsed since the onset of menarche (RR=1.44 each year, CI [1.19, 1.73]),[9] as well as secondary amenorrhea (6+ consecutive months) during the year prior to beginning training.[12,13] Specifically, Rauh and colleagues[12] observed an almost 3 times greater risk of developing a lower extremity stress fracture in females with secondary amenorrhea. Lappe et al[11] also observed that those trainees who self-reported having amenorrhea had a 91% higher risk of stress fracture than those who reported having at least

one menstrual period during the duration of training. Additionally, Cosman and colleagues[9] found physical training to have a distinctive effect on the menstrual cycles of all cadets, with 50% to 53.3% of cadets reporting one or less menstrual period in the first three months of training, indicating that sudden increases in physical activity can change menstruation patterns.

Diets lacking in calcium, Vitamin D, and iron, as well as lower body weight and sudden weight loss, can increase the risk of overuse injury to bone.[11,23,30] Compounded by decreased energy availability and sudden changes in physical activity, irregularities in menstruation in female trainees can also negatively impact bone health.[11-13] This interaction could explain the higher rates of stress fractures seen in females.[10,30,31]

PREVENTION OF LOWER LIMB STRESS FRACTURES

A variety of prospective studies have examined interventions to assess their effect on stress fracture incidence (**Table 2.4**), including leadership education,[27] shoe inserts,[35,36] and dietary supplementation.[11,37] Encouragingly, in a multiple intervention study performed at a U.S. Army BCT base, leadership was educated on a variety of injury prevention recommendations, including avoiding overtraining, achieving energy balance through nutrients within one hour following high-intensity exercise, and performing neuromuscular, agility, and balance training.[27] In addition, a physical therapist was employed to deliver consistent guidance on prevention activities, and commanders were provided with feedback on injury occurrence every training quarter. In a 2-year period, femoral neck stress injury incidence decreased by 58% and 50% in male and female

trainees, respectively,[27] demonstrating that prevention efforts can be effective for reducing the likelihood of a lower extremity stress fracture.

An assortment of insole options intended to positively influence shock transmission to bone has been researched in the militaries of South Africa[36] and the United Kingdom[35] with varied results. Neoprene insoles were examined during 9 weeks of training.[36] All members of the experimental and control groups wore standard military footwear and were exposed to the same training conditions, with only the addition of insoles to the experimental group. No differences were noted in incidence of lower extremity stress fractures between groups (1.4 (experimental) vs. 0.0 (control) injuries per 1000 participants per week).[36] In contrast, British researchers noted a significant difference in stress fracture incidence rates between two types of insoles—one made of coarse weave plastic and the other of polyurethane foam. A 6.5% incidence rate was found with the plastic insole, while the foam insole resulted in a 3.9% rate.[35] Unfortunately, there was no control group in this study, making it impossible to determine whether an insole positively affected incidence rates.[35] However, these results support the belief that distinct brands and components of insole assembly could affect stress fracture rates, requiring further investigation to determine necessary composition.

The prophylactic use of dietary supplements containing calcium, vitamin D, and risedronate in order to suppress bone turnover and prevent initial bone loss, has been studied with military personnel.[11,37] Daily calcium and vitamin D supplements in female Navy trainees resulted in a 20% lower stress fracture incidence,[11] while risedronate had no effect on injury.[37] If provided universally, it is important to note that the financial costs of dietary supplementation and/or insoles for foot gear are unknown. Given the limited

evidence supporting these interventions, other options such as leadership education, prevention enforcement, and injury surveillance may be more cost effective.[27]

SUGGESTIONS FOR ADDITIONAL STUDY

It is conceivable that, with knowledge that clearly identifies modifiable risk factors, effective steps can be taken to decrease the likelihood of each factor leading to injury. This would yield significant benefits to the U.S. Armed Forces, as well as to its new trainees on a personal, professional, and financial level. With such a wide range of testing procedures and treatment possibilities, future research must focus on how to successfully identify modifiable risk factors and apply prevention strategies in a large population of military basic trainees.

LIMITATIONS TO THIS REVIEW

There are widespread disparities in the clinical definition of, as well as the criteria of how to evaluate and treat, stress fracture injury within the medical community.[38,39] Smith[38] surveyed U.S. Army providers to determine preferences and practices associated with diagnoses of stress fractures. Results showed inconsistent responses regarding definition, symptomology, testing and criteria used to support diagnosis, and the amount of time stress fractures typically take to heal.[38] It is necessary to establish a standardized definition of stress fracture, as well as criteria and testing procedures required for diagnosis, so that these injuries can be identified and treated appropriately.[38]

SUMMARY AND CONCLUSIONS

It is widely accepted that the prevalence of stress fractures in the military population is a complex obstacle that must be addressed. The fundamental nature of military preparation requires constant bony exposure to repetitive stress. Compounded with additional risk factors, such as abrupt increases in physical activity, diminished bone and muscle strength, nutritional concerns, and menstrual irregularities, stress fracture incidence rates can escalate. The consequences of these injuries are costly and may even have important negative implications for military readiness beyond what has been examined. The extent and effect of lost training time and the rate of basic trainee discharge on military capabilities and productivity must be determined.

The lack of a universal clinical definition of these injuries in military medical settings also remains a concern.[39] In addition, treatment strategies that have been investigated in the hopes of accelerating and improving the return to duty process do not seem to have been successful.[40,41] Future efforts must establish a universal definition of stress fracture, as well as the conditions and procedures required for diagnosis, so that these injuries can be identified and treated properly and efficiently.[38,39]

Ultimately, efforts to identify individual stress fracture risk factors prior to beginning training are necessary to contend with the high incidence rates of this injury. At this time, there is no specific procedure in place to evaluate incoming basic trainees for the existence of risk factors or to predict the likelihood of developing a stress fracture. The overall body of literature is limited regarding the level of risk factors' contribution to injury, as well as appropriate testing and interventions for these factors in a large population of military basic trainees. With this knowledge, individualized, feasible, and effective

treatment plans can be created to address modifiable risk factors for injury, ideally reducing the incidence of stress fractures during BCT participation.

Table 2.1. Incidence rates of stress fractures in the U.S. Armed Forces, reported in studies with varying designs, sample characteristics, evaluation periods, and sample sizes.

Author(s)	Design	Cohort/Sample Characteristics	Evaluation Period	Sample Size (n)	Stress Fracture Incidence (%)
Beck et al[6]	Prospective cohort	U.S. Marine Corps basic trainees	12 weeks	Male: 624 Female: 693	Male: 6.1% Female: 5.3%
Cosman et al[9]	Prospective cohort	United States Military Academy (USMA) Cadets	4 years	Male: 755 Female: 136	Male: 5.7% Female: 19.1%
Cowan et al[15]	Prospective cohort	U.S. Army female basic trainees	180 days	Female: 1568	Female: 7%
Jones et al[3]	Prospective cohort	U.S. Army basic trainees	8 weeks	Male: 124 Female: 186	Male: 2.4% Female: 12.3%
Knapik et al[30]	Prospective cohort	U.S. Army basic trainees	BCT (exact time could vary)	Male: 475,745 Female: 107,906	Male: 1.9% Female: 8%
Lappe et al[42]	Prospective cohort	U.S. Army female basic trainees	8 weeks	Female: 3758	Female: 8.5%
Lappe et al[11]	RCT	U.S. Navy female basic trainees	8 weeks	Female: 5201	Calcium/VitD Supplementation: 6.8% Control: 8.6%
Montain et al[31]	Retrospective cohort	U.S. Armed Forces	BCT (exact time varies with branch)	Male: 421,461 Female: 90,141	Male: 1.9% Female: 8%
Rauh et al[12]	Prospective cohort	U.S. Marine Corps female basic trainees	13 weeks	Female: 824	Female: 6.8%
Reis et al[17]	Prospective cohort	U.S. Marine Corps male basic trainees	12 weeks	Male: 2137	Male: 6%
Shaffer et al[13]	Prospective cohort	U.S. Marine Corps female basic trainees	13 weeks	Female: 2962	Female: 5.1%

RCT: randomized controlled trial

Table 2.2. Rehabilitation time for stress fractures in military personnel.

Author(s)	Cohort/Sample Characteristics	Outcome Measure	Rehabilitation Time
Allen et al[40]	U.S. Army active duty Soldiers	End of functional progression	Tibia (wearing pneumatic leg brace): 37.2 ± 13.2 days Tibia (control): 45.6 ± 20.9 days
Rue et al[41]	U.S. Naval Academy plebes	Total days of symptoms	Tibia (utilized pulsed ultrasound): 56.2 ± 19.6 days Tibia (placebo): 55.8 ± 15.5 days
Sharma et al[43]	British Army recruits	Total rehabilitation time	Femur: 116 ± 17 days Calcaneus: 92 ± 12 days Tibia: 85 ± 11 days
Wood et al[16]	British Royal Marine recruits	Total rehabilitation time	Single metatarsal: 12.2 ± 1.3 weeks Multiple metatarsal: 15.4 ± 1.2 weeks Tibia: 21.1 ± 3.4 weeks Fibula: 13.3 ± 6.5 weeks Femur: 21.1 ± 4.1 weeks

Table 2.3. Risk factors of developing a stress fracture in male and female military personnel.

Author(s)	Cohort/Sample Characteristics	Risk Factors
Armstrong et al[23]	United States Naval Academy summer training program	Male: fewer push-ups during IST; greater weight loss at date of diagnosis since Day 1; higher Trait anxiety scores on the Spielberger State-Trait Anxiety Inventory; longer tibias; lower TBBMC Female: lower scores on 3 subscales of EDI; smaller thigh girth
Beck et al[6]	U.S. Marine Corps basic trainees	Male and Female: fewer sit-ups on physical fitness test, longer run times on initial physical fitness test; smaller thigh muscle CSA Male: smaller thigh and calf girth measurements; longer thigh length
Cosman et al[9]	USMA Cadets	Male and Female: smaller femoral neck diameter Male: < 7 hours per week of exercise in the year prior to entering USMA; lower tibial BMC; lower tibial cortical area Female: later age of menarche
Cowan et al[15]	U.S. Army female basic trainees	Female: failure of 5-minute step test
Knapik et al[30]	U.S. Army basic trainees	Female and Male: older age; lower body weight; lower BMI; race/ethnicity other than black Male: height 180 cm or taller Female: gender
Lappe et al[42]	U.S. Army female basic trainees	Female: older age; race other than black; lower adult weight; corticosteroid use; >10 alcoholic drinks per week; current/past smoking; decreased history of regular exercise; DMPA use in white women
Lappe et al[11]	U.S. Navy female basic trainees	Female: amenorrhea; older age; Depo contraceptive use; history of smoking; slower 1.5 mile entry run time
Mattila et al[10]	Finnish conscripts	Male and Female: older age; poor muscle strength (overall score created from scores on horizontal jump distance and number of sit-ups, push-ups, pull-ups, and back lifts); poor performance on 12 minute run test; lower BMI Female: gender
Montain et al[31]	U.S. Armed Forces	Male and Female: race other than black Female: gender
Rauh et al[12]	U.S. Marine Corps female basic trainees	Female: slower initial run times; self-rated poor fitness; secondary amenorrhea (6 or more consecutive missed periods)
Shaffer et al[13]	U.S. Marine Corps female basic trainees	Female: Hispanic origin; slower run times on IST; lower self-rating of current fitness; non-runners before training; no menses or secondary amenorrhea during year prior to training

Valimaki et al[14]	Finnish male military recruits	Male: taller height; decreased distance capable of running in 12 minutes; lower femoral neck and total hip BMC and BMD (after adjusting for other factors)
Yanovich et al[34]	Israeli Defense Forces Soldiers at beginning of service	Female: anemia, iron deficiency anemia

IST: Initial Strength Test; TBBMC: total body bone mineral content; EDI: Garner's Eating Disorder Inventory; CSA: cross-sectional area; BMC: bone mineral content; BMI: body mass index; DMPA: depo-medroxyprogesterone acetate (type of contraceptive); BMD: bone mineral density

Table 2.4. Intervention studies on stress fractures in military personnel.

Author(s)	Cohort/Sample Characteristics	Intervention	Outcome
House et al[35]	British Royal Marine recruits	Saran insole (course weave plastic) vs. SAI insole (cellular polyurethane foam)	Saran: 6.5% incidence rate SAI: 3.9% incidence rate P = 0.002
Lappe et al[11]	U.S. Navy female basic trainees	2000 mg calcium, 800 IU Vitamin D daily	Experimental Group: 5.3% incidence rate Placebo Group: 6.6% incidence rate P = 0.026
Milgrom et al[37]	Israeli male infantry recruits	30 mg of risedronate for first 10 days, followed by maintenance dose once a week for the duration of training	Experimental Group: 14.5% incidence rate Placebo Group: 13.2% incidence rate P = 0.7
Schwellnus et al[36]	South African military recruits	Neoprene insoles	Experimental Group: 1.4 injuries per 1000 participants per week Control Group: 0.0 injuries per 1000 participants per week P > 0.05
Scott et al[27]	U.S. Army basic trainees	Leadership education, leadership enforcement of methods, injury surveillance	FNSI incidence decreased 58% in males and 50% in females from 2008 to 2010.

FNSI: Femoral neck stress injury

CHAPTER 3

GENERAL METHODOLOGY

AIM 1

Study Design

This study was a cross-sectional design utilizing a single data collection session to assess (1) the inter-rater reliability of novice examiners in reading the Quick Star Excursion Balance Test (QSEBT) reach distances in real-time utilizing pieces of tape marked with centimeters and (2) the test-retest reliability of the first successful trial in each of the 8 directions on the QSEBT. An additional goal was to determine the time needed to for a novice examiner to complete the QSEBT.

Participants

Healthy students and faculty/staff between the ages of 18-40 at the University of South Carolina in Columbia, South Carolina (SC) were eligible for participation. These students and faculty/staff were chosen because they are similar in age, physical fitness, and location to the basic trainees entering BCT at Fort Jackson, SC. Participants were excluded if they reported an injury or medical condition that limited mobility, including the use of assistive devices, as that would prevent them from completing the testing. In addition, each participant was asked to complete the Physical Activity Readiness Questionnaire (PAR-Q) and AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire

(Appendix A). Blood pressure was measured by the research staff. The research staff followed the recommendations of the questionnaires when determining if the participant was eligible to participate in the study.[44] If a participant answered “yes” to any of the questions on the PAR-Q or “true” to at least one history question or 2 cardiovascular risk factors on the AHA/ACSM Questionnaire, he/she was excluded.

Testing Procedure

Setting. Participants completed informed consent and the testing procedures in a gymnasium setting at the University of South Carolina. Prior to the data collection session, 8-pronged “stars” were taped to the floor using white athletic tape. Centimeters were then marked on each piece of tape using a tape measure, increasing in distance away from the center of the star.

Examiners. The primary investigator instructed and provided a visual demonstration to all examiners on how to administer and score the QSEBT appropriately. Examiners were provided with a script of standardized instructions to read to each participant **(Appendix B)**. Examiners asked the primary investigator questions until comfortable with test administration and had little to no formal experience with the QSEBT prior to data collection.

Data Collection Procedure. Participants eligible for the study completed the following physical performance test:

Quick Star Excursion Balance Test – Without shoes or socks to avoid the possibility of slipping, participants were asked to balance on their dominant leg first with the great toe in the center of the star while reaching as far as possible with the other leg

(Figure 3.1) in 8 directions, all 45 degrees from the previous direction **(Figure 3.2)**.[45,46] Directions were completed in the following order: anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anteromedial. To complete the medial direction, the participant was instructed to reach behind the stance leg **(Appendix B)**. The test was repeated with the non-dominant leg as stance leg. Leg dominance was determined by asking the participant which foot he/she would choose to kick a ball.[47] The distance the participant was able to reach while maintaining balance was measured by rounding down to the last centimeter reached. If the participant was not able to return to the center of the star following each reach while maintaining balance, they were asked to repeat the trial.[45,46] Two examiners independently recorded the first successful distance reached simultaneously for all 8 directions to assess inter-rater reliability of the testing procedures. The time from the beginning of instructions to the completion of the test was also recorded in minutes and seconds. After completion of the QSEBT with both extremities as stance leg, the participant was asked to repeat the test to determine test-retest reliability.

Physical performance measurements were recorded on the Data Collection Recording Sheet for each participant **(Appendix C)**.

Statistical Analysis

Inter-rater and test-retest reliabilities were determined for the QSEBT measures by the use of intra-class correlation coefficients (ICC)[48,49] with 95% confidence intervals. The ICC form was selected based on the experimental design. Since each participant was rated by examiners from a larger population of potential examiners, inter-rater reliability was determined by calculating a one-way random-effects model.[50] Test-retest reliabilities of the

QSEBT measures were calculated based on a single-rater, absolute agreement, 2-way mixed-effects model.[50] An ICC of >0.90 was interpreted to be excellent reliability, 0.90 to 0.75 as moderate reliability, 0.75 to 0.5 as good reliability, and <0.5 as poor reliability.[50]

The standard error of the measurement (SEM) was calculated as:

$$SEM = SD(pooled)*\sqrt{(1-ICC)}$$

where SD = the standard deviation of the mean differences of comparisons. The minimal detectable change (MDC) with a 95% confidence interval was calculated as:

$$MDC_{95} = SEM*(\sqrt{2})*(1.96).$$ [49]

Time needed to complete the QSEBT was calculated as a mean ± standard deviation in minutes and seconds. IBM SPSS Statistics 25.0 statistical software (SPSS, Inc., Chicago, IL) was used for all analyses.

AIM 2

Study Design

This study was conducted as a prospective longitudinal cohort study of basic trainees during 10 weeks of U.S. Army BCT to establish the predictive validity between individual and combinations of physical performance measures in the reporting of a back or lower extremity musculoskeletal injury to a medical provider during U.S. Army BCT at Fort Jackson, SC. Baseline physical performance measures included the QSEBT, WBLT, and SLWS. The dichotomous outcome studied was whether or not the participant reported at least one musculoskeletal injury to a medical provider during the 10-week BCT program. It was approved by the U.S. Army Medical Research and Materiel Command Institutional Review Board.

Participants

Fort Jackson in Columbia, SC serves as the primary BCT center for the U.S. Army. Male and female basic trainees in one battalion participating in U.S. Army BCT at Fort Jackson who were at least 17 years old were eligible to participate in this study. Exclusion criteria included age greater than 42 years, self-identified chronic or acute injuries or illnesses that would limit exercise, and self-identified history of use of glucocorticoid drugs in the previous 2 years, bone-modifying disorders, endocrine disorders, and metal implants. Females that were pregnant or breastfeeding and basic trainees that were already on a medical profile at the time of informed consent were also excluded.

Testing Procedure

Setting. Participants completed baseline surveys and physical performance testing during the first week of BCT. In addition, participants were asked to complete a weekly self-report of injury throughout the 10 weeks of training. These testing sessions were completed at Fort Jackson, SC.

Participant Preparation. Informed consent was obtained at the beginning of BCT. Basic trainees were brought to a briefing that described the study, inclusion and exclusion criteria, and any risks associated with the data collection procedures. Superiors of the basic trainees were not in attendance at the briefing, and care was taken to ensure that basic trainees understood that participation was voluntary. Potential participants were given time to ask any questions regarding the study procedures to research staff. An ombudsperson was present at the briefing and during the informed consent process. Following consent, participants were scheduled to return to complete baseline surveys, anthropometrics, body

composition, and physical performance testing during the first week of BCT. Participants were also scheduled to follow up on a weekly basis to self-report injury throughout BCT.

Data Collection Procedure. An emphasis was placed on determining physical performance testing procedures that would provide an assessment on lower extremity balance, flexibility, strength, and endurance. The QSEBT, WBLT, and SLWS were chosen to assess these parameters for their time efficiency and simplicity of instruction and grading.

Prior to the data collection session, "stars" were taped to the floor using white athletic tape, with each piece of tape 45 degrees from the next. Centimeters were then marked on the tape beginning at the center of the star in each of the 8 directions **(Figure 3.1)**. For the WBLT, tape measures (in centimeters) were secured to the floor, reaching away at 90 degrees from the wall, with 0 centimeters beginning at the wall **(Figure 3.2)**. Goniometers were secured at 60 degrees with white tape for ease and efficiency in measuring knee flexion for the SLWS. The primary investigator instructed all examiners on how to administer and score each test appropriately **(Appendix B, D, E)**. There was a total of 9 examiners utilized on a rotating basis throughout data collection—all certified athletic trainers or physical therapy students.

Physical Performance Testing. Each participant completed physical performance testing in the order listed below so that the potential fatigue following the SLWS would not affect balance. Physical performance testing procedures are outlined below:

Quick Star Excursion Balance Test – This test was utilized to assess lower extremity stability and functional symmetry. Without shoes or socks to avoid the possibility of slipping, participants were asked to balance on their dominant leg first with the great toe in the center of the star while reaching as far as possible with the other leg **(Figure 3.3)** in

8 directions, all 45 degrees from the previous direction **(Figure 3.4)**.[45,46] Directions were completed in the following order: anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anteromedial. To complete the medial direction, the participant was instructed to reach behind the stance leg **(Appendix B)**. The test was repeated with the non-dominant leg as stance leg. The distance the participant was able to reach while maintaining balance was measured by rounding down to the last centimeter reached. If the participant was not able to return to the center of the star following each reach while maintaining balance, they were asked to repeat the trial.[45,46] The first successful trial was recorded in real time for analysis. To normalize reach distance to the participant's leg length, leg length was measured from the inferior aspect of the anterior superior iliac spine to the distal aspect of the lateral malleolus bilaterally **(Figure 3.5)**.[46] Leg length was recorded to the tenth of a centimeter. Leg dominance was recorded by asking the participant the leg they would choose to kick a ball.[47]

Weight-Bearing Lunge Test – This test was utilized to assess ankle range of motion and gastrocnemius/soleus complex flexibility. Without shoes or socks to allow proper viewing, participants began in a lunge position facing a wall and were asked to perform a lunge to touch the wall with the patella of their lead leg without lifting his/her heel from the ground. The participant then moved the foot of the lead leg away from the wall until they were no longer able to reach the wall while keeping proper form **(Figure 3.6) (Appendix D)**. The maximum distance of the great toe from the wall at which the participant was still able to reach the wall with proper form was recorded to the tenth of a centimeter.[51,52] Each participant began with their right leg as their lead leg.

Single-Leg Wall Squat – This test was utilized to assess core and thigh musculature strength and endurance. Wearing shoes, participants performed a single leg wall sit with the squat leg knee flexed to 60 degrees. Knee flexion angle was confirmed using a goniometer. The fulcrum was established as the lateral epicondyle of the femur, the stationary arm landmark as the greater trochanter of the femur, and the movement arm landmark as the lateral malleolus of the fibula **(Figure 3.7)**. The participant's arms were placed in an X pattern across his/her chest, and the non-squat leg was lifted from the floor **(Figure 3.8)**. Participants were asked to hold the position for as long as possible, up to one minute **(Appendix E)**. The test was terminated if the participant moved out of the positioning. The test was repeated bilaterally. Whether or not the participant was able to hold the position for one minute and the amount of time the position was held in seconds was recorded.

Physical performance measurements were recorded on the Data Collection Recording Sheet for each participant **(Appendix F)**.

Additional Covariates for Analysis. This study was part of a larger study conducted by the United States Army Research Institute of Environmental Medicine (USARIEM). The following measures were provided as covariates for analysis:

Anthropometrics and Body Composition – Standing height was measured without shoes using a stadiometer to the nearest tenth of a centimeter. Body weight was measured using a calibrated electronic scale to the nearest tenth of a kilogram. Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared. Body composition was measured using dual-energy x-ray absorptiometry (DEXA) (Lunar I-DEXA, GE Healthcare, Madison, WI). Total body estimates of bone mineral density and

percent fat were calculated using procedures provided by the manufacturer (Encore, version 11.40, Lunar Corp., Madison, WI).

Demographic and Background Questionnaire **–** Multiple investigators have researched the effect of poor physical conditioning and muscle strength in an individual prior to beginning training programs, which is strongly associated with history and severity of injury and the inability to participate in physical activity or activities of daily living.[6,9,10,12,13,23] Time since the onset of menarche[9] and degrees of amenorrhea[11-13] have also been associated with injury incidence. Therefore, participants were asked to complete a short questionnaire regarding prior physical activity levels and menstruation history. The questions are available in **Table 3.1**.

Outcome Measure.

Weekly Self-Report of Injury Questionnaire – At the end of each week of BCT, participants reported to a scheduled data collection session to complete the weekly injury questionnaire. Participants were asked to report any injuries (defined as any ache, pain, or discomfort in the bones, muscles, ligaments, and tendons) within the previous 7 days, whether the injury was reported to a medical provider, how the injury limited activities (no limitations, minimally limited, moderately limited, significantly limited), and the severity of the injury (no pain/discomfort, mild pain/discomfort, moderate pain/discomfort, severe pain/discomfort) **(Figure 3.7)**. Research staff were available during completion of the weekly questionnaire to answer any questions the participants may have had regarding wording or question structure.

Statistical Analysis

This study was a prospective, cohort design that quantified measures at the beginning of BCT and followed participants through training to identify who did and did not seek medical care for a lower extremity musculoskeletal injury. Statistical approaches were used to determine the combination of measures that best predict the likelihood of pursuing medical care for these injuries.

The cohort was defined as U.S. Army basic trainees at Fort Jackson, SC during BCT, with entry and exit time points defined by their 10-week BCT program. The outcome studied was whether or not a participant reported at least one musculoskeletal injury to a medical provider during the 10-week BCT program. The "reported injury group" was defined as basic trainees that self-reported at least one lower extremity musculoskeletal injury that they also reported to a medical provider. The "no report of injury group" was defined as basic trainees that completed the demands of BCT and did not report a lower extremity musculoskeletal injury to a medical provider during training.

Participants were not included in the analysis if they did not participate in the self-report of injury questionnaires and/or complete the baseline survey questionnaires, body composition testing, and physical performance measures.

For the QSEBT, each reach distance was normalized to the participant's leg length, by dividing each reach distance by the participants' leg length and then multiplying by 100. An 8-direction composite score was calculated as an average of the normalized values from the anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anterolateral directions bilaterally. A 3-direction composite score was an average of the

normalized values from the anterior, posterolateral, and posteromedial directions bilaterally.

Descriptive statistics, including means and standard deviations for continuous variables and frequencies and proportions for categorical variables, were calculated to describe the characteristics of the participants. Independent variables included performance on the QSEBT, success/fail of the SLWS, and the distance recorded during the WBLT. Levels of categorical variables were combined to allow for convergence of data during analysis.

Mann-Whitney U and independent t-tests were used to compare differences between sexes, as well as the outcome variable, for the independent variables. Comparisons made utilizing the independent t-test met the following assumptions:[53] (1) the dependent variable was continuous, (2) the independent variable consisted of dichotomous, independent groups, (3) the observations were independent, (4) there was a large sample size, (5) the dependent variables were normally distributed, and (6) there was homogeneity of variances. Dependent variables that did not meet the above assumptions were analyzed using the Mann-Whitney U test. The following assumptions were met for the use of the Mann-Whitney U test: (1) the dependent variable was continuous or ordinal, (2) the independent variable was dichotomous and independent, and (3) the observations were independent. Descriptive statistics and group comparisons were conducted using IBM SPSS Statistics 25.0 statistical software (SPSS, Inc., Chicago, IL).

Multiple logistic regression was implemented, modeling a dichotomous outcome (reported injury or no reported injury) from the independent variables listed above. Due to significant differences observed in the independent variables between sexes, the multiple

logistic regression models were stratified by sex. Bivariate relationships of independent variables to the outcome variable were examined, and variables with a p-value less than 0.25 in the bivariate analysis were utilized in the initial model. A backward elimination procedure was used to remove predictors not contributing to the model, and decisions on predictor removal were confirmed using the Likelihood Ratio Test.[54] Using maximum likelihood estimation (MLE), odds ratios and 95% Wald Confidence Limits were calculated for variables remaining in the model. Covariates included in the bivariate analysis were age, height, weight, BMI, bone mineral density, body fat percentage, history of sport participation, activity level prior to BCT (including general exercise, running, and weight training), age at onset of menarche, and number of menstrual periods annually. Following model selection, the Likelihood Ratio Test, Score Test, and Wald Test were utilized to determine if the final model provided a better fit to the data than a null model. The models were then evaluated using a MLE-based pseudo R^2, rescaled R^2, area under the ROC curve, and the Homer and Lemeshow Goodness-of-Fit Test. Logistic regression assumptions were confirmed for the final models: (1) independent observations, (2) the linearity of the log(odds) of the continuous variables, and (3) the regression error followed a binomial distribution. Multiple logistic regression analyses were completed using SAS version 9.4 (SAS Institute, Inc., 2013).

Table 3.1. Baseline survey questions included as covariates in analysis.

Survey Question	**Recoded Response Options**
Have you ever played or participated in any sports/organized physical activity?	Yes
	No
Compared to others of the same age and sex, how would you rate yourself as to the amount of physical activity you performed prior to entering training?	Less active
	About the same
	More active
Over the last 2 months, prior to entering BCT, what was the average number of times per week you exercised or played sports for at least 30 minutes at a time?	< 1 time per week
	2-4 times per week
	> 5 times per week
How does your level of exercise over the past month compare to your exercise or sport frequency during the entire year prior to entering BCT?	Less
	About the same
	More
Over the last 2 months, prior to entering BCT, what was the average number of times per week you ran or jogged?	< 1 time per week
	2-4 times per week
	> 5 times per week
Over the last 2 months, prior to entering BCT, how often did you perform weight training exercises?	< 1 time per week
	2-4 times per week
	> 5 times per week
At what age did you have your first period?	< 10 years old
	10-12 years old
	13-15 years old
	> 15 years old
Over the last 12 months, how many menstrual periods have you had?	0-6
	7-9
	10-12
	≥ 13

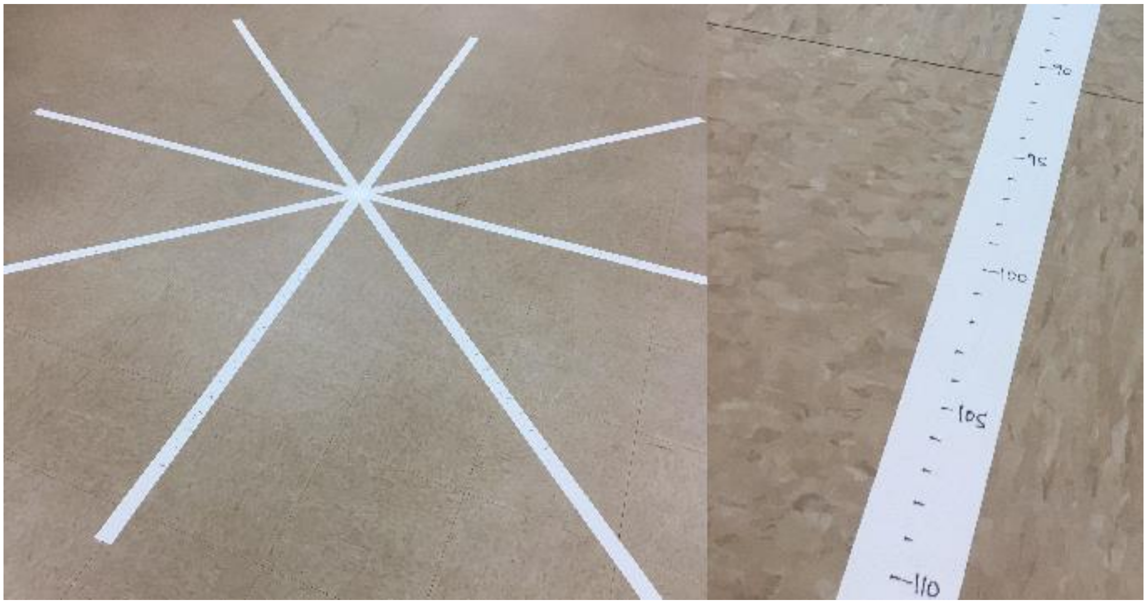

Figure 3.1. Set-up for the QSEBT.

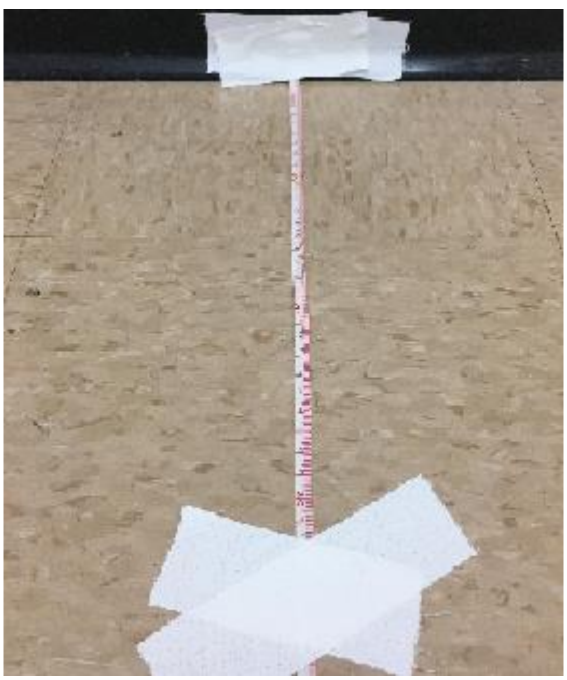

Figure 3.2. Set-up for the WBLT.

Figure 3.3. Participant foot positioning during the QSEBT.

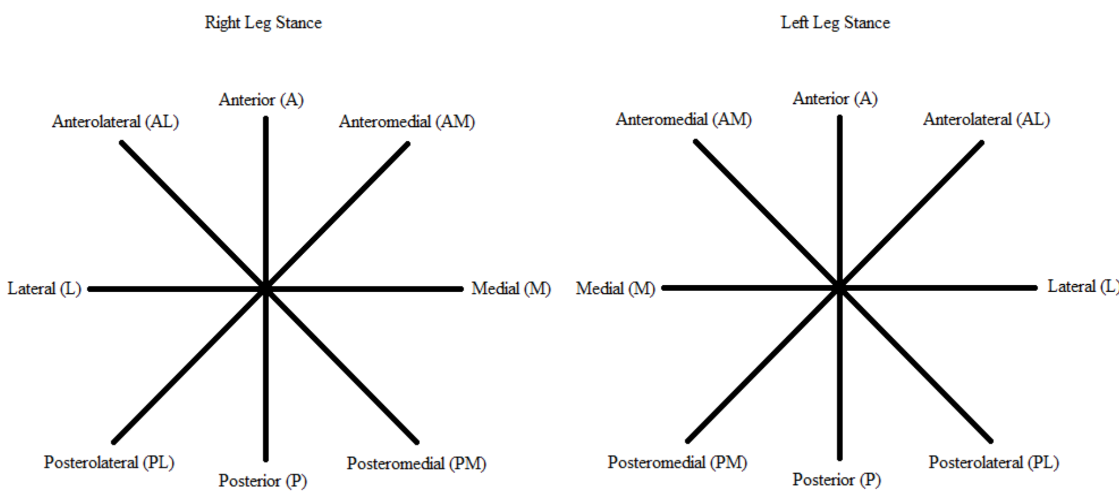

Figure 3.4. QSEBT reach directions for the left and right stance legs.

Figure 3.5. Participant positioning for WBLT.

Figure 3.6. Leg length measurement (from anterior superior iliac spine to most distal lateral malleolus).

Figure 3.7. Knee flexion angle (60 degrees) for the SLWS confirmed using a goniometer (fulcum: lateral epicondyle of the femur, stationary arm: greater trochanter of femur, movement arm: lateral malleolus).

Figure 3.8. Participant positioning for the SLWS.

Location	Injury? Y: Yes, *answer remaining columns* ➡ N: No, *continue with next body part*	**Was this injury reported to a medical provider?** Y: Yes N: No	**How did this limit your activities?** 0: No limitations 1: Minimally limited 2: Moderately limited 3: Significantly limited	**Rate the severity of this injury on a scale of 0-10?** 0: No pain/discomfort (0/10) 1: Mild pain/discomfort (1-3) 4: Moderate pain/discomfort (4-6) 7: Severe pain/discomfort (7-10)
a. Head	Y N	Y N	0 1 2 3	0 1 4 7
b. Neck	Y N	Y N	0 1 2 3	0 1 4 7
c. Chest/Ribs	Y N	Y N	0 1 2 3	0 1 4 7
d. Back	Y N	Y N	0 1 2 3	0 1 4 7
e. Shoulder	Y N	Y N	0 1 2 3	0 1 4 7
f. Arm	Y N	Y N	0 1 2 3	0 1 4 7
g. Elbow	Y N	Y N	0 1 2 3	0 1 4 7
h. Wrist/ and/Fingers	Y N	Y N	0 1 2 3	0 1 4 7
i. Hip/Pelvis/ Groin	Y N	Y N	0 1 2 3	0 1 4 7
j. Thigh/ Hamstring	Y N	Y N	0 1 2 3	0 1 4 7
k. Knee	Y N	Y N	0 1 2 3	0 1 4 7
l. Lower Leg (calf)	Y N	Y N	0 1 2 3	0 1 4 7
m. Ankle	Y N	Y N	0 1 2 3	0 1 4 7
n. Foot/Toe	Y N	Y N	0 1 2 3	0 1 4 7

Figure 3.9. Weekly self-report of injury questionnaire.

CHAPTER 4

RELIABILITY OF TESTING PROCEDURES FOR THE QUICK STAR EXCURSION BALANCE TEST[2]

ABSTRACT

Context: The Star Excursion Balance Test (SEBT) mimics the functional demands of physical activity and sport and is used to dynamically assess postural control. Recent studies have reported moderate to excellent intra-rater, inter-rater, and test-retest reliabilities of measures obtained from the SEBT. However, the currently described testing procedures are too time consuming for large-scale application.

Objective: To determine the inter-rater and test-retest reliabilities of the shortened testing version of the SEBT—Quick Star Excursion Balance Test (QSEBT).

Design: Cross-sectional descriptive study.

Setting: University facility.

Participants: Forty-six healthy participants (21 males, 25 females; age = 23.5±4.3 years; height = 170.6±8.3 cm; mass = 72.7±15.4 kg).

Intervention(s): Participants were evaluated by 2 novice examiners simultaneously in performance of the 8 tasks of the QSEBT bilaterally. The QSEBT was then repeated to assess test-retest reliability of the first successful trial.

[2] Hand AF. To be submitted to the *Journal of Athletic Training*.

Main Outcome Measure(s): Group-wise inter-rater and test-retest reliability of measures were assessed using the intraclass correlation coefficient (ICC). The magnitude of error for individual measures was investigated by calculating the standard error of measurement (SEM) and MDC_{95}.

Results: ICCs for inter-rater comparisons of the QSEBT for all 8 reach directions ranged from 0.90 to 0.97 for the right stance leg and from 0.83 to 0.98 for the left stance leg. Composite SEM and MDC_{95} were 1.24 cm and 3.44 cm and 1.26 cm and 3.50 cm for the right and left stance legs, respectively. ICCs for test-retest reliability of the QSEBT ranged from 0.64 to 0.88 with the right stance leg and from 0.67 to 0.79 for the left stance leg. Composite SEM and MDC_{95} were 2.25 cm and 6.25 cm and 2.75 cm and 7.62 cm for the right and left stance legs, respectively.

Conclusions: Measures obtained from the QSEBT have evidence of reliability for novice examiners when they are instructed on how to administer the test and provided with oral instructions to read to participants. Reaching distance in all 8 directions bilaterally has moderate to excellent inter-rater reliability in real time when utilizing pieces of tape marked with centimeters. Researchers and clinicians can utilize the QSEBT in a short period of time to assess dynamic postural control.

Keywords: clinical balance test, dynamic postural control

INTRODUCTION

Clinicians typically include dynamic postural-control exercises in the rehabilitation of injury. These exercises involve a range of anticipated movement around a base of support, in an attempt to mimic the functional demands—including range of motion, strength, and proprioception—of physical activity and sport.[45,55] The Star Excursion

Balance Test (SEBT) is currently being used in rehabilitation and research settings as a dynamic postural-control assessment[55] to measure (1) proprioceptive deficits following injury,[56-60] (2) improvements during rehabilitation, and (3) the risk of lower extremity injury during physical activity.[20] To perform the SEBT, the participant must balance on one leg and reach as far as possible with the other leg in designated directions while maintaining balance **(Figure 4.1)**.[45] A farther reaching distance indicates superior dynamic postural control.[55]

Kinzey and Armstrong[61] first reported test-retest reliability of the SEBT for the anteromedial, anterolateral, posteromedial, and posterolateral directions, measured 7 days apart on 20 healthy participants. Intraclass correlation coefficients (ICC) and standard error of the measurement (SEM) ranged from 0.67 to 0.87 and 3.43 to 4.78, respectively.[61] Hertel and colleagues[62] later reported the intra-rater and inter-rater reliabilities of all 8 reach directions of the SEBT over 2 days with 16 healthy participants. On day one, intra-rater ICCs ranged from 0.78 to 0.96 and inter-rater ICCs ranged from 0.35 to 0.84. Day 2 showed ranges of 0.82 to 0.96 and 0.81 to 0.93, respectively.[62] Most recently, Gribble et al[46] reported non-normalized inter-rater ICCs for the anterior, posteromedial, and posterolateral directions ranging from 0.89 to 0.94 after testing the SEBT on 29 participants using trained examiners at two locations.[46]

Findings from the SEBT also have evidence of predictive validity. Plisky and colleagues[20] collected measurements in the anterior, posteromedial, and posterolateral directions of the SEBT prior to the season in 235 high school basketball players and documented time loss injuries throughout the season. At the end of the season, participants that measured greater than 4 centimeters difference in the anterior direction between

extremities were 2.5 times more likely to experience a lower extremity (LE) injury during the season. In addition, females that performed a composite reach distance less than 94% of their limb length were 6.5 times more likely to experience a LE injury.[20] These findings indicate the SEBT could be utilized to identify physically active individuals with increased likelihood of injury due to decreased dynamic postural control.

However, a key concern of utilizing the SEBT is the length of time required to obtain measures. Demura and Yamada[63] estimated that measuring the 8 reach directions with 10 trials each bilaterally would take approximately 60 minutes per participant. In addition, currently reported reliability studies for the SEBT have utilized a common measurement procedure in which the examiner marks the tape at the location of the maximum reach distance, and then measures the distance with a tape measure.[61,64,65] The measurement procedure itself requires a substantial amount of time for each reach, making the procedure potentially too time consuming for a large-scale data collection.

In addition, previous studies utilizing the SEBT have utilized both practice and test trials for each reaching direction, ranging from 4 to 11 reaches in each direction.[20,58,60,62,66] Both Munro and Herrington[64] and Robinson and Gribble[65] completed studies in an attempt to reduce the number of trials needed for the SEBT and determined that reach distances stabilized after 4 trials;[64,65] however, 4 trials for each reach direction would still potentially result in substantial testing time when applied to a large group, which would be necessary for athletic or military screening for lower extremity functional control. Considering the potential value of the SEBT, a shortened version would improve its feasibility for use on large samples; however, it is unknown if a reduced number of trials would adversely influence the reliability of measures.

The primary purposes of this study were to determine (1) the inter-rater reliability of novice examiners in reading the Quick Star Excursion Balance Test (QSEBT) reach distances in real-time utilizing pieces of tape marked with centimeters and (2) the test-retest reliability of using the first successful trial in each of the 8 directions on the QSEBT. A secondary purpose was to determine the time needed to for a novice examiner to complete the QSEBT. The goal was to determine if the testing procedures could be successful for large-scale application in clinical and research settings.

METHODS

Participants

Forty-six healthy students, faculty, and staff at the University of South Carolina (21 males, 25 females; age = 23.5±4.3 years; height = 170.6±8.3 cm; mass = 72.7±15.4 kg) participated in this study. Participants were excluded if they were experiencing an injury or medical condition that limited mobility or revealed risk factors for medical concerns that could be exacerbated with physical activity. To evaluate for the presence of risk factors, each participant completed the Physical Activity Readiness Questionnaire (PAR-Q), AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire, and a blood pressure assessment. Recommendations of the questionnaires were followed when determining if the participant was eligible to participate in exercise.[44] If a participant answered "yes" to any of the questions on the PAR-Q or "true" to at least one history question or 2 cardiovascular risk factors on the AHA/ACSM Questionnaire, he/she was excluded. Healthy young adults were chosen for this investigation because they would be similar to a typical military or athletic population who would undergo a large group pre-

participation screening. Each participant also read and signed an informed consent form approved by the University of South Carolina Institutional Review Board.

Protocol

Prior to the data collection session, stars were taped to the floor using white athletic tape, with each piece of tape 45 degrees from the next piece of tape. Centimeters were then marked on the tape beginning at the center of the star in each of the 8 directions **(Figure 4.2)**. On the day of data collection, the primary investigator instructed and provided a visual demonstration to all examiners (athletic trainers and physical therapy students) on how to administer and score the QSEBT appropriately. Examiners were provided with a script of standardized instructions to read to each participant **(Table 4.1)** and allowed an opportunity to ask the primary investigator questions until comfortable with test administration. Examiners had little to no formal experience with the QSEBT prior to this instruction.

All participants completed the same protocol of the QSEBT outlined below during a single testing session. Two independent examiners simultaneously recorded the first distance reached successfully for all 8 directions to assess inter-rater reliability of reading the distances reached in real-time. The time from the beginning of instructions to the completion of the test was also recorded in minutes and seconds. After completion of the QSEBT with both extremities as stance leg, the participant was asking to repeat the test to determine test-retest reliability of the measures.

Performance of the QSEBT

Standardized instructions and a visual demonstration were given to each participant prior to beginning the testing procedures. Barefoot[46] participants first single-limb balanced on the foot of their dominant leg with their great toe in the center of the star[20] while reaching as far as possible with their contralateral leg in 8 directions, all 45 degrees from the previous direction.[45,46] Leg dominance was determined by asking the participant the leg they would choose to kick a ball.[47] Reach directions were completed in the following order: anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anteromedial **(Figure 4.1)**. To complete the medial reach direction, the participant was instructed to reach behind the stance leg. Each reaching task was then repeated using the non-dominant leg as stance leg. The distance the participant was able to reach while maintaining balance (successful trial) was measured by rounding down to the farthest centimeter reached. If the participant was not able to return to the center of the star following each reach direction while maintaining balance, he/she was asked to repeat the trial[45,46]

Data Reduction

For each of the 8 reaching directions on the QSEBT and for both extremities, the reach distance was recorded in centimeters by both examiners. The sums of all 8 directions were also averaged to create a composite score for each extremity. This resulted in 18 QSEBT variables for both the inter-rater and test-retest reliability analyses.

Statistical Analysis

Inter-rater reliabilities at the group level were determined by calculating a single-rater, absolute agreement, one-way random-effects model[50] to obtain intraclass correlation coefficients (ICCs) for each of the 8 reach directions and the composite score for both extremities. Test-retest reliability of the QSEBT was calculated based on a single-rater, absolute agreement, 2-way mixed-effects model.[50] Reliability at the individual level was determined by calculating the SEM ($SEM=SD(pooled)*\sqrt{(1-ICC)}$) and the minimal detectable change ($MDC_{95}=SEM*(\sqrt{2})*(1.96)$).[49] IBM SPSS Statistics 25.0 statistical software (SPSS, Inc., Chicago, IL) was used for all analyses.

Since the number of participants and examiners meets reliability study recommendations of at least 30 heterogeneous samples and 3 raters, an ICC of >0.90 was interpreted to be excellent reliability, 0.90 to 0.75 as moderate reliability, 0.75 to 0.5 as good reliability, and <0.5 as poor reliability.[50] Time needed to complete the QSEBT was calculated as a mean ± standard deviation in minutes and seconds.

RESULTS

The inter-rater reliability for all 8 reach directions was moderate to excellent, with the ICCs ranging from 0.90 to 0.97 with the right extremity as the stance leg and from 0.83 to 0.98 with the left as stance leg. SEM values for the composite score was 1.24 cm for the right stance leg and 1.26 cm for the left stance leg. The MDC_{95} for the composite score was 3.44 cm for the right stance leg and 3.50 cm for the left stance leg **(Table 4.2)**.

For the right stance leg, test-retest reliability for 6 of the 8 reach directions was moderate, ranging from 0.75 to 0.88. Test-retest reliability for the right stance leg medial

(ICC=0.64) and anteromedial (ICC=0.73) directions had good reliability. For the left stance leg, test-retest reliability for 4 of the 8 reach directions was moderate, ranging from 0.75 to 0.79. Test-retest reliability for the left stance leg posterior (ICC=0.71), posteromedial (ICC=0.73), medial (ICC=0.67), and anteromedial (ICC=0.72) directions had good reliability. SEM values for the composite score was 2.25 cm for the right stance leg and 2.75 cm for the left stance leg. The MDC_{95} for the composite score was 6.25 cm for the right stance leg and 7.62 cm for the left stance leg **(Table 4.3)**.

The ICC, 95% confidence interval for the ICC, SEM, and MDC_{95} for all inter-rater reliability and test-retest reliability measurements for the QSEBT are available in Tables 4.2 and 4.3, respectively. The average amount of time taken to complete the QSEBT the first time from the onset of directions through completion of both extremities as stance leg was 3 minutes and 38 seconds (SD = 62.14 seconds).

DISCUSSION

The goal of this study was to determine the feasibility of using the QSEBT for large samples in clinical and research settings as a baseline measurement of dynamic postural control, which would realistically require the use of multiple examiners with varying experience with the QSEBT. Assessment of the QSEBT demonstrated moderate to excellent inter-rater reliability in all 8 reaching directions and on both extremities across multiple novice investigators with different experience levels. Only one other study has examined the inter-rater reliability of using more than 2 examiners in the assessment of the SEBT. Gribble et al[46] utilized 5 examiners at two separate testing sites, after providing training on how to administer the testing procedures. The authors reported ICCs for the

non-normalized maximum excursion distances for the anterior, posteromedial, and posterolateral reaching directions that ranged from 0.89 to 0.93,[46] which are similar to the moderate to excellent ICCs of this study. Methodologically, however, our studies differed. Gribble[46] randomized and utilized the examiners individually in the assessment of the test, in contrast to our examiners who graded the same reach distance simultaneously to examine the reliability of reading reach distances in real time. Hertel[62] has also reported moderate to excellent inter-rater reliability ICCs for the SEBT between two examiners (0.81 to 0.93 on day 2 of SEBT performance), also having examiners test participants individually. Even with varying methodology across research studies, the body of evidence continues to suggest the use of multiple examiners with varying experience levels does not compromise reliability of the SEBT. Our findings support the use of multiple examiners with different experience levels when administering the QSEBT is not likely to be different than those findings reported for the longer SEBT.

Previous research studies have also acknowledged the need for time-saving procedures in the implementation of the SEBT. Prior to a study performed by Gribble et al[46] in 2013, common practice in administering the SEBT was to allow 6 practice trials before utilizing an average of 3 or more trials as the test outcome. In an attempt to find time-saving solutions, Gribble[46] assessed the inter-rater reliability of a maximum reach distance and the average reach distance over three trials. The ICCs for the normalized anterior, posteromedial, and posterolateral reaching directions for maximum and average reaching distances ranged from 0.86 to 0.90 and 0.88 to 0.91, respectively. The similarities in inter-rater reliabilities were interpreted to mean that the use of maximum only trials may be beneficial when working with large sample sizes to reduce the time required for

testing.[46] Two additional studies assessed the number of trials needed before reaching distances would stabilize. Both Munro and Herrington[64] and Robinson and Gribble[65] determined that maximum excursion distances stabilized after 4 trials, indicating a reduction in the number of practice and test trials may be warranted.

Following 6 practice and 3 test trials, Plisky and colleagues[20] indicated the maximum excursion reached within the 3 trials of the SEBT could be utilized to identify physically active individuals with increased likelihood of injury due to decreased dynamic postural-control. Since the test-retest reliability of the first successful trial in the current study was good to moderate (0.64 to 0.88) across both extremities, future research must examine if the maximum excursion reached on the first successful trial during the QSEBT could be utilized to identify increased risk of injury. This knowledge could greatly expand the application of the QSEBT due to time-saving options.

This is also the first study to utilize real-time viewing in the assessment of reaching distance. Testing protocol of the SEBT required examiners to mark the floor at the point of maximum reaching distance and then go back and measure that distance with a tape measure.[61,64,65] The moderate to excellent inter-rater reliability of reading and recording maximum reach distances in real-time indicate the time-saving change implemented in this study does not compromise the reliability of the SEBT.

A secondary purpose of this study was to determine the time necessary for a novice examiner to properly instruct a participant in the performance of the QSEBT and complete 8 reaching directions bilaterally, when recording the first successful reach in real-time. The average time needed to complete the testing protocol was 3 minutes and 38 seconds, which is a stark difference from the 60 minutes estimated by Demura and Yamada.[63] Clinicians

and researchers will be able to use this information to determine the feasibility of implementing the QSEBT in their practice and protocols.

The main limitation to the current study included potential inconsistencies in the skill set of the examiners. While all examiners were trained by the same investigator and provided the same script of participant instructions, examiners were not tested or observed on their knowledge and implementation of the procedures. While participant instructions were standardized, it is possible that examiners could have varying opinions on what indicated a failed trial, which could affect the first successful trial recorded. The sample was limited to healthy people who would be candidates for screening. Our findings cannot be generalized to individuals who are being evaluated following lower extremity injury.

CONCLUSIONS

The QSEBT provides reliable measures on healthy individuals who are tested by novice examiners. Reaching in all 8 directions on both extremities has moderate to excellent inter-rater reliability in real-time when utilizing pieces of tape marked with centimeters, averaging only 3 minutes and 38 seconds per test. The test-retest reliability for the first successful trial in all 8 directions has good to moderate reliability. Future research must determine if the distance reached on the first successful trial is predictive of lower extremity injury. Researchers and clinicians can utilize the QSEBT quickly as a screening tool, without expensive equipment, to assess dynamic postural-control. These findings cannot be generalized to individuals who have current lower extremity impairment.

Table 4.1. Standardized instructions given to participants prior to performance of the QSEBT.

1. "You will stand in the middle of the grid on one foot and will be reaching as far as you possibly can along each of these eight lines with your other foot while maintaining balance on your stance leg."
2. "You will make a light touch with your toes on the line and return back to a double leg stance at the center, maintaining balance the entire time."
3. "Do not transfer weight with the light touch or allow the contact to affect your overall balance."
4. "When crossing your body, you must reach behind your stance leg."
5. "If I determine that you use your reaching leg for a substantial amount of support at any time or if you lose balance on the stance leg throughout the test, the trial must be repeated."
6. "You must also keep your stance foot at the center of the grid."
7. "We will be measuring how far you are able to reach and still perform the test correctly."

Table 4.2. Inter-rater reliability, standard error of measurement, and minimal detectable change for reach distances on the QSEBT.

Reach Direction *Stance Leg*	***ICC***	***95% Confidence Interval (ICC)***	***SEM (cm)***	***MDC_{95} (cm)***
Anterior				
Right	0.90	(0.83, 0.94)	2.64	7.33
Left	0.83	(0.71, 0.90)	3.04	8.43
Anterolateral				
Right	0.94	(0.89, 0.96)	1.52	4.21
Left	0.93	(0.87, 0.96)	1.95	5.42
Lateral				
Right	0.97	(0.95, 0.98)	1.48	4.10
Left	0.94	(0.89, 0.97)	1.83	5.08
Posterolateral				
Right	0.97	(0.95, 0.98)	1.85	5.14
Left	0.98	(0.96, 0.99)	1.60	4.42
Posterior				
Right	0.90	(0.82, 0.94)	3.40	9.42
Left	0.95	(0.91, 0.97)	2.76	7.65
Posteromedial				
Right	0.90	(0.82, 0.94)	3.48	9.66
Left	0.86	(0.77, 0.92)	4.40	12.21
Medial				
Right	0.90	(0.83, 0.95)	2.66	7.37
Left	0.90	(0.82, 0.94)	2.89	8.00
Anteromedial				
Right	0.95	(0.92, 0.97)	1.81	5.02
Left	0.87	(0.78, 0.93)	2.56	7.11
Composite				
Right	0.97	(0.95, 0.98)	1.24	3.44
Left	0.97	(0.95, 0.98)	1.26	3.50

ICC: Intraclass correlation coefficient; SEM: Standard error of measurement; MDC_{95}: minimal detectable change at the 95% confidence interval; cm: centimeters

Table 4.3. Test-retest reliability, standard error of measurement, and minimal detectable change for reach distances on the QSEBT.

Reach Direction *Stance Leg*	***ICC***	***95% Confidence Interval (ICC)***	***SEM (cm)***	***MDC_{95} (cm)***
Anterior				
Right	0.84	(0.73, 0.91)	3.30	9.14
Left	0.75	(0.59, 0.85)	3.44	9.53
Anterolateral				
Right	0.75	(0.59, 0.85)	3.73	10.35
Left	0.77	(0.60, 0.87)	3.49	9.67
Lateral				
Right	0.88	(0.79, 0.93)	2.84	7.87
Left	0.75	(0.48, 0.87)	4.00	11.08
Posterolateral				
Right	0.82	(0.65, 0.90)	4.32	11.98
Left	0.79	(0.59, 0.89)	4.86	13.47
Posterior				
Right	0.80	(0.65, 0.89)	4.98	13.82
Left	0.71	(0.48, 0.84)	6.33	17.53
Posteromedial				
Right	0.79	(0.63, 0.88)	4.87	13.49
Left	0.73	(0.56, 0.84)	5.95	16.51
Medial				
Right	0.64	(0.43, 0.79)	4.54	12.59
Left	0.67	(0.46, 0.80)	4.99	13.83
Anteromedial				
Right	0.73	(0.56, 0.84)	4.26	11.80
Left	0.72	(0.55, 0.83)	3.58	9.93
Composite				
Right	0.90	(0.76, 0.95)	2.25	6.25
Left	0.86	(0.62, 0.94)	2.75	7.62

ICC: Intraclass correlation coefficient; SEM: Standard error of measurement; MDC_{95}: minimal detectable change at the 95% confidence interval; cm: centimeters

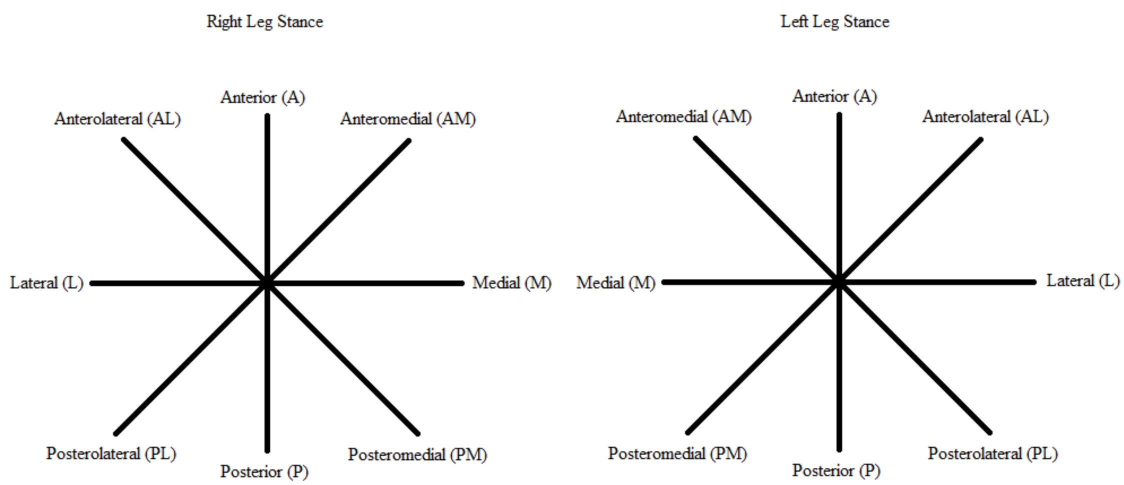

Figure 4.1. QSEBT reach directions for the left and right stance legs.

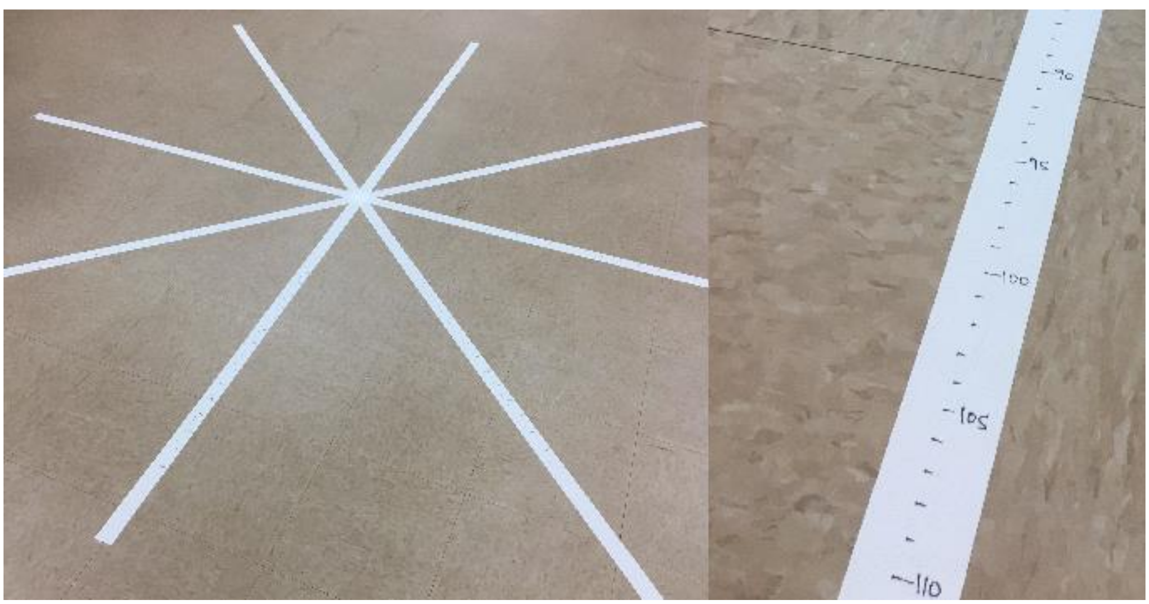

Figure 4.2. Set-up for the QSEBT.

CHAPTER 5

A TESTING BATTERY'S PREDICTIVE VALIDITY OF REPORTING AN INJURY DURING U.S. ARMY BASIC COMBAT TRAINING[3]

ABSTRACT

Context: The physical activity requirements of the United States (U.S.) Armed Forces result in a high incidence rate of musculoskeletal injuries annually. Previous research on balance, ankle dorsiflexion, and muscle strength measurements have indicated that assessments may be beneficial at identifying physically active individuals with an increased odds of lower extremity injury.

Objective: To establish the predictive validity of the Quick Star Excursion Balance Test (QSEBT), Weight-Bearing Lunge Test (WBLT), and Single-Leg Wall Squat (SLWS) in the reporting of a back or lower extremity musculoskeletal injury to a medical provider during U.S. Army Basic Combat Training (BCT).

Design: Prospective longitudinal cohort study.

Setting: One U.S. Army BCT battalion at Fort Jackson, South Carolina.

Participants: Four hundred and twenty-seven U.S. Army basic trainees (141 females, 286 males; age: 21.4 ± 3.6 years; height: 171.6 ± 9.4 cm; weight: 73.6 ± 13.3 kg).

Intervention(s): During the first week of BCT, participants completed baseline survey questionnaires on previous activity levels and menstruation patterns, body composition

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[3] Hand AF. To be submitted to the *Journal of Athletic Training*.

testing, and physical performance measures (QSEBT, WBLT, SLWS). Participants then followed up weekly throughout BCT to complete self-report of injury questionnaires.

Main Outcome Measure(s): Normalized reaching distances on the QSEBT bilaterally, wall distances on the WBLT bilaterally, and successful trials on the SLWS were analyzed.

Results: In the first week of BCT, female participants reached for a shorter distance than males with their non-dominant leg in the QSEBT (3-Direction Composite: 81.73 ± 9.34 to 85.68 ± 10.79 cm, $p = 0.04$) after normalizing to leg length and measured shorter distances on the WBLT bilaterally (dominant: 9.88 ± 3.26 to 10.17 ± 3.92 cm, $p = 0.03$; non-dominant: 9.68 ± 3.14 to 10.00 ± 3.81 cm, $p = 0.02$). Ultimately, 34.4% of all participants (53.9% of female participants, and 24.8% of male participants) reported an injury to a medical provider during training. We estimate each centimeter increase in the reach distance of the 3-direction composite QSEBT score (dominant stance leg) is associated with a 2.1% reduction (OR = 0.979, 95% CI [0.958, 1.001], $p = 0.06$) in the odds of a basic trainee in reporting an injury during BCT, after adjusting for sex, bone mineral density, and the average days of 30 minutes of exercise per week in the two months prior to BCT.

Conclusions: Dynamic postural control assessment measured by the QSEBT may be helpful in identifying basic trainees who have increased odds of reporting a lower extremity or back injury during BCT. Future research should examine the predictive validity of the QSEBT on specific diagnoses of injury, injuries that cause lost time, and attrition from training.

Keywords: dynamic postural control, ankle dorsiflexion, overuse injury

INTRODUCTION

The physical activity requirements of the United States (U.S.) Armed Forces have produced a concerning incidence rate of musculoskeletal injuries in military personnel. Across the Armed Forces, almost three-quarters of a million musculoskeletal injuries were reported in one calendar year, with 82.3% of these diagnosed as overuse injuries. Of the overuse injuries reported, 41.8% and 34.7% of those injuries occurred to the lower extremity and vertebral column, respectively.[1] In the basic trainee population specifically, exercise-related incidence of injury ranges from 14% to 42% in male basic trainees and 27% to 61.7% in females,[2-5] resulting in limited duty of 10 days per 100 person-weeks and 32 days per 100 person-weeks, respectively.[3] Given the high prevalence of musculoskeletal injuries during basic training and the negative impact of lost time on training effectiveness and financial costs, there is a need to develop programs that are effective in identifying basic trainees with a higher odds of an overuse injury during training.

Balance assessments have been previously utilized to predict injury risk to the lower extremity.[55] Previous studies have indicated high school basketball players with increased static postural sway during unilateral tasks[67] and less dynamic postural control measured by the Star Excursion Balance Test (SEBT) are more likely to sustain lower extremity injuries.[20] McGuine and colleagues[67] examined baseline static postural sway during unilateral eyes open and closed balance tests in high school basketball players. Following the basketball season, participants with higher postural sway scores suffered almost 7 times as many ankle sprains than the participants with low sway scores.[67] Dynamic postural control has also been previously assessed by the use of the SEBT in the high school basketball population to study its effect on injury incidence. After collecting

baseline scores in the anterior, posteromedial, and posterolateral directions, Plisky and colleagues[20] reported basketball players with a more than 4 cm difference in the their anterior reach direction between extremities were 2.5 times more likely to have a lower extremity injury.

Decreased ankle dorsiflexion has also been identified as a risk factor for patellar tendinopathy,[68] lower leg fractures and sprains,[69] and anterior cruciate ligament injury.[70] For this reason, measurements of ankle dorsiflexion are commonly used in clinical and research settings, and measures obtained during weight-bearing are beneficial to observe a measurement representative of functional range of motion.[71] Functional measures of ankle dorsiflexion obtained during the Weight-Bearing Lunge Test (WBLT) have displayed good to excellent inter-rater (ICC = 0.80 to 0.99) and intra-rater (ICC = 0.65 – 0.99) reliabilities, with a minimal detectable change of 1.6 and 1.9 centimeters, respectively.[71] In a study performed by Pope and colleagues[26] on 1,093 male Australian Army recruits, a survival analysis revealed that the range of ankle dorsiflexion measured by the WBLT was a predictor ($p = 0.03$) of 5 specific types of lower extremity injury (tendo-Achilles lesions, lateral ankle sprains, stress fractures of the foot or tibia, periostitis of the tibia, and anterior tibial compartment syndrome).[26] In addition, Pope concluded the least flexible dorsiflexion range measured was associated with 2.5 times the risk of the injury compared to those participants with average ankle dorsiflexion. For lateral ankle sprains specifically, the least flexible dorsiflexion range was at 5 times greater risk of injury than those within average ranges.

Compromised hip muscle function has also been associated with patellofemoral pain[72] and overuse injuries.[73] A single-leg squat task is commonly used in clinical settings

to evaluate hip muscle function. In a study performed by Crossley and colleagues[74] on 34 asymptomatic participants, the participants characterized as “good” performers of a single-leg squat task had significantly earlier onset of myoelectric activity in the anterior gluteus medius, posterior gluteus medius, as well as greater hip abduction torque. Ultimately, Crossley concluded the single-leg squat task could be used to identify hip muscle dysfunction.[74]

Efforts to identify individual risk factors prior to beginning BCT are necessary to contend with the high incidence rates of musculoskeletal injuries during training. Therefore, the purpose of this

study was to establish the predictive validity of the measures obtained from the QSEBT, WBLT, and Single Leg Wall Squat (SLWS) in the report of a back or lower extremity musculoskeletal injury in U.S. Army basic trainees. It was hypothesized that basic trainees (1) not able to hold the single-leg wall squat for one minute, (2) with less ankle dorsiflexion, and (3) less dynamic postural control would be at an increased odds of reporting a back or lower extremity musculoskeletal injury.

METHODS

Study Design

This investigation was a prospective, longitudinal cohort study of basic trainees during 10 weeks of U.S. Army BCT and completed as part of a larger investigation conducted by the United States Army Research Institute of Environmental Medicine (USARIEM). The study was approved the U.S. Army Medical Research and Materiel Command Institutional Review Board.

Participants

Male and female basic trainees of at least 17 years of age from one U.S. Army BCT battalion at Fort Jackson, South Carolina were eligible to participate in this study. Of enrolled participants, 427 (141 females, 286 males; age: 21.4 ± 3.6 years; female height: 162.1 ± 6.3 cm; female mass: 63.7 ± 8.6 kg; male height: 176.3 ± 6.7 cm; male mass: 78.4 ± 12.5 kg) were included for analysis. Exclusion criteria included age greater than 42 years, self-identified chronic or acute injuries or illnesses that would limit exercise, and self-identified history of use of glucocorticoid drugs in the previous 2 years, bone-modifying disorders, endocrine disorders, and metal implants. Females that were pregnant or breastfeeding and basic trainees that were already on a medical profile at the time of informed consent were also excluded.

Protocol

Informed consent was obtained at the beginning of BCT. Basic trainees attended a briefing that described the study, inclusion and exclusion criteria, and any risks associated with procedures. Superiors of the basic trainees were not in attendance at the briefing, and care was taken to ensure that basic trainees understood that participation was voluntary. Potential participants were given time to ask any questions regarding the study procedures, and an ombudsperson was present at the briefing and during the informed consent process. Following consent, participants were scheduled to return to complete baseline surveys, anthropometrics, body composition, and physical performance testing during the first week of BCT. Participants were also scheduled to follow-up on a weekly basis to self-report injury throughout BCT. Research staff was available during completion of baseline surveys

and the weekly questionnaire to answer any questions the participants may have regarding wording or question structure.

Physical Performance Tests

Each participant completed physical performance testing in the order listed below so that the potential fatigue following the SLWS would not affect dynamic postural stability. Physical performance testing procedures are outlined below:

Quick Star Excursion Balance Test – This test was utilized to assess lower extremity stability and dynamic postural control. Barefoot, participants were asked to balance on their dominant leg first with the great toe in the center of the star while reaching as far as possible with the other leg **(Figure 5.1)** in 8 directions, all 45 degrees from the previous direction[45,46] **(Figure 5.2)**. Directions were completed in the following order: anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anteromedial. To complete the medial direction, the participant was instructed to reach behind the stance leg. The test was repeated with the non-dominant leg. The distance the participant was able to reach while maintaining balance was measured by rounding down to the last centimeter reached. If the participant was not able to return to the center of the star following each reach while maintaining balance, he/she was asked to repeat the trial.[45,46] The first successful trial in each direction was recorded for analysis. Limb length was measured from the inferior aspect of the anterior superior iliac spine to the distal aspect of the lateral malleolus bilaterally[46] **(Figure 5.3)** and recorded to the tenth of a centimeter. Each reach distance was normalized to height by dividing by the participant's leg length and then multiplying by 100. An 8-direction composite score was calculated as an average

of the normalized values from the anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anterolateral directions. Similar to Plisky's[20] study, a 3-direction composite score was also calculated as an average of the normalized values from the anterior, posterolateral, and posteromedial directions.[20] Leg dominance was recorded by asking the participant the leg they would choose to kick a ball.[47]

Weight-Bearing Lunge Test – This test was utilized to assess ankle range of motion and gastrocnemius/soleus complex flexibility. Barefoot, participants began in a lunge position facing a wall and were asked to perform a lunge to touch the wall with the patella of their lead leg without lifting his/her heel from the ground. The participant then moved the foot of the lead leg away from the wall until he/she was no longer able to reach the wall while keeping proper form **(Figure 5.4)**. The maximum distance of the great toe from the wall at which the participant was still able to reach the wall with proper form was recorded to the tenth of a centimeter.[51,52] Participants began with their right leg as their lead leg.

Single-Leg Wall Squat – This test was utilized to assess core and thigh musculature strength and endurance. Participants performed a single leg wall sit with the squat leg knee flexed to 60 degrees. Knee flexion angle was confirmed using a goniometer. The fulcrum was established as the lateral epicondyle of the femur, the stationary arm landmark as the greater trochanter of the femur, and the movement arm landmark as the lateral malleolus of the fibula **(Figure 5.5)**. The participant's arms were placed in an X pattern across his/her chest, and the non-squat leg was lifted from the floor **(Figure 5.6)**. Participants were asked to hold the position for as long as possible, up to one minute. The test was terminated if the participant moved out of the positioning. The test was repeated

bilaterally. Whether or not the participant was able to hold the position for one minute and the amount of time the position was held in seconds was recorded.

Weekly Self-Report of Injury Questionnaire – At the end of each week of BCT, participants reported to a scheduled data collection session in their company area to complete the weekly injury questionnaire. Participants were asked to report any injuries (defined as any ache, pain, or discomfort in the bones, muscles, ligaments, and tendons) within the previous 7 days and to indicate if the injury was reported to a medical provider.

Covariates

The following established risk factors for musculoskeletal and bone stress injury were collected and provided by USARIEM to be considered as covariates in the analyses: body mass index (BMI), age, bone mineral density, body fat percentage, history of sport participation, activity level prior to BCT (including general exercise, running, and weight training), age at onset of menarche, and number of menstrual periods annually. Standing height was measured without shoes using a stadiometer to the nearest tenth of a centimeter. Body weight was measured using a calibrated electronic scale to the nearest tenth of a kilogram. BMI was calculated as body weight in kilograms divided by height in meters squared.[75] Body composition was measured using dual-energy x-ray absorptiometry (DEXA) (Lunar I-DEXA, GE Healthcare, Madison, WI). Total body estimates of bone mineral density and percent fat were calculated using procedures provided by the manufacturer (Encore, version 11.40, Lunar Corp., Madison, WI). Participants also completed a short questionnaire regarding prior physical activity levels and menstruation

history. Survey questions and group classification for the categorical variables are available in Table 5.1.

Statistical Analysis

Descriptive statistics, including means and standard deviations for continuous variables and frequencies and proportions for categorical variables, were utilized to describe the characteristics of the participants. Independent variables included performance on the QSEBT, success/fail of the SLWS, and the distance recorded during the WBLT. The outcome studied was whether or not a participant reported at least one musculoskeletal injury to a medical provider during the 10-week BCT program. The "reported injury" group was defined as basic trainees that self-reported at least one lower extremity musculoskeletal injury to a medical provider. The "no report of injury" group was defined as basic trainees that completed the demands of BCT and did not report a lower extremity musculoskeletal injury to a medical provider during training. Due to established differences between sexes regarding musculoskeletal injury, Mann-Whitney U and independent t-tests were used to compare differences between sexes, as well as the outcome variable, for the independent variables. Descriptive statistics and group comparisons were conducted using IBM SPSS Statistics 25.0 statistical software (SPSS, Inc., Chicago, IL).

Multiple logistic regression was applied to assess the relationship between the measures taken prior to beginning BCT and the report of musculoskeletal injury. Due to significant differences in measures between sexes, as well as established physiological and behavioral differences, regression models were stratified by sex. Using SAS version 9.4 (SAS Institute Inc., 2013) statistical package, the bivariate relationships of independent

variables to the outcome variable were examined, and convergence criteria were satisfied. The referent level for the SLWS was chosen as a successful attempt and the referent level for history of sport participation was chosen as yes. All other categorical variables were compared to the average across all participants' responses. Variables with a p-value less than 0.25 in the bivariate analysis were utilized in the initial model. Backward elimination procedure was then used to remove unnecessary predictors, and decisions made on predictor removal were confirmed using the likelihood ratio test.

RESULTS

Injury Rate

Of enrolled participants, 427 completed baseline survey questionnaires, body composition testing, baseline physical performance measures, and participated in the self-report of injury questionnaires to obtain the outcome variable. There were 147 participants that reported at least one injury to a medical provider during BCT (34.4% of all participants; 53.9% of female participants, and 24.8% of male participants) **(Table 5.2)**. Of the 280 participants that did not report an injury during BCT, 91.3% of the weekly self-report of injury questionnaires were completed.

Sex Differences

Female participants were shorter than male participants (162.07 ± 6.28 to 176.34 ± 6.67 kg, $p < 0.0001$) weighed less (63.72 ± 8.57 to 78.40 ± 12.51 kg, $p < 0.001$), and had a lower body mass index (BMI) (24.23 ± 2.66 to 25.19 ± 3.66 kg/m^2, $p = 0.02$). Females also displayed a higher body fat percentage than males (32.44 ± 5.43 to 23.05 ± 6.61 %, p =

0.001) and a lower bone mineral density (1.17 ± 0.10 to 1.27 ± 0.12 g/cm^2, p = 0.03) **(Table 5.3)**. After normalizing to leg length, female participants also reached for a shorter distance with their non-dominant leg in the QSEBT (8-Direction Composite: 78.95 ± 8.46 to 81.69 ± 9.70 cm, p = 0.04; 3-Direction Composite: 81.73 ± 9.34 to 85.68 ± 10.79 cm, p = 0.04) **(Table 5.4)**. Females also measured shorter distances than males in the WBLT bilaterally (dominant: 9.88 ± 3.26 to 10.17 ± 3.92 cm, p = 0.03; non-dominant: 9.68 ± 3.14 to 10.00 ± 3.81 cm, p = 0.02) **(Table 5.5)**. There was no significant difference observed in the successful trials of the SLWS between sexes bilaterally **(Table 5.6)**. Comparisons between sexes on responses to the survey questions are available in Table 5.7. Additional questions for females also and response rates are available in Table 5.8.

Injury Group Differences

There were no significant differences observed in the measurements on the 8-Direction Composite QSEBT, 3-Direction Composite QSEBT, WBLT, and the differences in measurements between the extremities on both tests between the report and no report of injury groups bilaterally **(Table 5.9)**. There was also no significant difference observed in the proportion of successful trials of the SLWS between the report and no report of injury groups bilaterally **(Table 5.10)**.

Male Basic Trainees

In male basic trainees, we estimate that each centimeter increase in the reach distance of the 3-direction composite QSEBT score (dominant stance leg) is associated with a 2.5% reduction (OR = 0.975, 95% CI [0.949, 1.002], p = 0.07) in the odds of

reporting an injury during BCT, after adjusting for distance measured on the weight-bearing lunge test (non-dominant leg) and the average days of 30 minutes of exercise per week in the two months prior to BCT **(Table 5.11)**.

Female Basic Trainees

The QSEBT, WBLT, and SLWS did not contribute to the logistic regression model for the female basic trainees. However, females that participated in at least 30 minutes of exercise for at least 5 days a week on average in the 2 months prior to entering BCT were less likely to report an injury during training. We estimate that the odds of a female basic trainee that exercised more than 5 times a week of reporting an injury during BCT is 0.399 (95% CI [0.205, 0.776], $p = 0.007$) times the odds of those trainees that exercised less than 5 days a week, after adjusting for bone mineral density **(Table 5.12)**.

All Basic Trainees

To compare the odds of injury between males and females, we created a logistic regression model for all basic trainees containing predictors of interest for both sexes. The following covariates were included in this model: sex, bone mineral density, 3-direction composite QSEBT score, and the average days of 30 minutes of exercise per week in the two months prior to BCT. Males were used as the referent group. Following analysis, females had a significantly higher odds of reporting an injury during training. We estimate that the odds of a female basic trainee reporting an injury during training was 2.4 times (OR = 2.433, 95% CI [1.519, 3.898], $p = 0.0002$) the odds of male basic trainees, after adjusting for bone mineral density, their 3-direction composite QSEBT score (dominant

stance leg), and the average days of 30 minutes of exercise per week in the two months prior to BCT.

In addition, we estimate each centimeter increase in the reach distance of the 3-direction composite QSEBT score (dominant stance leg) is associated with a 2.1% reduction (OR = 0.979, 95% CI [0.958, 1.001], p = 0.06) in the odds of a basic trainee in reporting an injury during BCT, after adjusting for sex, bone mineral density, and the average days of 30 minutes of exercise per week in the two months prior to BCT **(Table 5.13)**.

DISCUSSION

Differences in Sex

While it is not surprising that male and female basic trainees were different in height, weight, and body fat percentage, there was a difference observed in the percentage of reported injuries during BCT between sexes. More than one-half of the females (53.9%) participating in BCT reported at least one injury to a medical provider during training, in comparison to less than one in 4 (24.8%) male basic trainees (OR = 2.433, 95% CI [1.519, 3.898], p = 0.0002). These injury rates are consistent with previous published exercise-related incidence of injury during U.S. Army BCT ranging from 14% to 42% in male basic trainees and 27% to 61.7% in females.[2-5]

In comparison of physical performance measures, female participants reached for a shorter distance with their non-dominant leg on the QSEBT (8-Direction Composite: 78.95 ± 8.46 to 81.69 ± 9.70 cm, p = 0.04; 3-Direction Composite: 81.73 ± 9.34 to 85.68 ± 10.79 cm, p = 0.04), after normalizing the reach distances to height. These findings differ

from previous sex comparisons on SEBT excursion distance. Gribble and Hertel[66] compared 12 males and 18 females to assess the differences in raw and normalized reach distances in men and women on all 8 of the SEBT reach distances. Raw excursion scores were significantly different between males and females in the posterior, posteromedial, and medial directions. After normalizing the reach directions to height, these differences were no longer significant.[66] Since the investigators did not find a difference in reach distances between the right and left extremities, these values, however, were combined from both the right and left reach distances of the participants. While dominant leg comparisons were not different between sexes in our study, non-dominant comparisons did indicate a decreased dynamic postural control in females. These findings suggest future use of the QSEBT may see differences in performance between sexes if leg dominance is taken into consideration.

In addition, females in our study had shorter distances than males in the WBLT bilaterally (dominant: 9.88 ± 3.26 to 10.17 ± 3.92 cm, $p = 0.03$; non-dominant: 9.68 ± 3.14 to 10.00 ± 3.81 cm, $p = 0.02$). Due to the WBLT testing procedures, these differences could be explained by the significant height differences between sexes; however, these findings suggest future efforts in identifying injury risk during BCT may need to be considered for both sexes individually, instead of all basic trainees assessed together as one group.

Therefore, with the observed differences in sex comparisons, the logistic regression procedures in this study were stratified by sex. Following a backward elimination procedure, none of the physical performance testing measures contributed to the female only model. In comparison, the odds ratio for the dominant 3-direction composite QSEBT score (OR = 0.975, 95% CI [0.949, 1.002], $p = 0.068$) and non-dominant WBLT (OR =

1.072, 95% CI [0.995, 1.155], $p = 0.068$) approached significance for the male basic trainees. This could be due to the self-report nature of the outcome variable. The predictive validity of the QSEBT and WBLT must continue to be examined for diagnosed injuries and attrition from training in males.

Dynamic Balance Assessments in the Prediction of Injury

Since the testing procedures of the QSEBT require an individual to continue to maintain balance even while moving around a base of support, this test more closely mimics the functional requirements of physical activity and participation in BCT, when compared to a static postural sway assessment.[55] While existing literature seems to agree that the SEBT is useful in detecting individual balance deficits in injured individuals,[60,76,77] there is only limited published information describing its ability to identify participants who are at an increased likelihood of lower extremity injury.[20,67]

In a study performed by Stiffler and colleagues,[78] pre-season SEBT measurements in 147 collegiate athletes were examined for their relationship to noncontact injuries to the knee or ankle during a competitive season. The injured participants (defined by being removed from sporting activities for at least one day) reached for significantly less distance in all reach directions and in the composite score while standing on the non-dominant leg ($p \leq 0.01$). In addition, normalized asymmetry values were larger for the injured participants ($p = 0.002$).[78] Gonell and colleagues[79] also found a differences between injured (defined by at least one lost training day) and uninjured soccer players (n=74) in the asymmetry of the reach in the posteromedial direction. These findings differed from our study in that we found no differences between the reported injury group and no report of

injury group between extremities in the composite or asymmetry scores. This could be due to the self-report nature of our outcome measure versus a formally diagnosed injury (with lost time) outcome. It is conceivable that basic trainees experience discomfort on a daily basis, due to the requirements and physical demands of BCT. A pain or discomfort reported to a medical provider and a formally diagnosed injury causing lost time are distinctively different.

Limitations

Even though all participants were from the same battalion at the same BCT base, the participants were from 5 different companies with different leadership. It is possible all participants may not have been exposed to the same demands associated with BCT, which could affect the incidence of injury. It is also conceivable that the atmosphere in each company was different in regard to the basic trainee's comfort in reporting an injury to a medical provider. Since the outcome variable was solely if an injury was reported, the reporting rate could have been affected by basic trainees in some companies choosing to not report injuries and vice versa.

In addition, due to the self-report nature of injuries, it is likely that some injuries reported to a medical provider were not collected by research staff. Participants may have been discharged due to an injury during training and were not available to report the injury on a weekly self-report questionnaire.

Future Study

Future study must examine the predictive validity of the measures of the QSEBT, WBLT, and SLWS on diagnosed injuries from a medical provider, injuries that require lost time from training, and attrition from BCT. Due to the procedure for reporting injuries in this study, risk factors for specific injuries and attrition from training was not available. More detailed analyses of diagnosed injuries, lost time from training, and attrition rates will allow for a more through and comprehensive understanding of the predictive validity of the physical performance tests.

Future study should also examine the effect of interventions and preventative protocols to increase dynamic postural control and ankle dorsiflexion and to determine if the intervention causes a decrease in incidence rates to the lower extremity during BCT. A survival analysis should also be considered to examine the time to the diagnosed injury. Knowledge regarding timing of a variety of musculoskeletal injuries could assist in the scheduling of proper preventative protocols. It would also be beneficial to clinicians if there was an established relationship between WBLT measured distances in centimeters to ankle dorsiflexion measured in degrees using a goniometer. In addition, optimal WBLT distances must be determined to allow clinicians to interpret how to decrease injury through improvements in ankle dorsiflexion.

CONCLUSIONS

Female basic trainees were at an increased odds of reporting at least one injury to a medical provider during BCT than male basic trainees. Female basic trainees also measured shorter distances than males on the WBLT bilaterally and shorter normalized non-dominant

QSEBT reach distances than males, suggesting future use of the QSEBT may see performance differences between sexes if leg dominance is recorded and considered. Future efforts in identifying injury risk during BCT may need to be considered for both sexes individually.

Dynamic postural control assessment measured by the QSEBT may be helpful in identifying basic trainees at an increased odds of reporting a lower extremity or back injury during BCT. Clinicians and researchers can consider a large-scale application of the QSEBT in the identification of individuals that may be more likely to sustain an injury. Future study must identify the extent of the QSEBT's predictive validity in formally diagnosed injuries, lost time from training, and attrition, providing a greater understanding of its usefulness for large-scale application for physically active populations.

Table 5.1. Covariate group classification for categorical variables from baseline history questions of U.S. Army basic trainees at Fort Jackson, SC.

Survey Question	**Group Classification**
Have you ever played or participated in any sports/organized physical activity?	Yes
	No
Compared to others of the same age and sex, how would you rate yourself as to the amount of physical activity you performed prior to entering training?	Less active
	About the same
	More active
Over the last 2 months, prior to entering BCT, what was the average number of times per week you exercised or played sports for at least 30 minutes at a time?	< 1 time per week
	2-4 times per week
	> 5 times per week
How does your level of exercise over the past month compare to your exercise or sport frequency during the entire year prior to entering BCT?	Less
	About the same
	More
Over the last 2 months, prior to entering BCT, what was the average number of times per week you ran or jogged?	< 1 time per week
	2-4 times per week
	> 5 times per week
Over the last 2 months, prior to entering BCT, how often did you perform weight training exercises?	< 1 time per week
	2-4 times per week
	> 5 times per week
At what age did you have your first period?	< 10 years old
	10-12 years old
	13-15 years old
	> 15 years old
Over the last 12 months, how many menstrual periods have you had?	0-6
	7-9
	10-12
	≥ 13

Table 5.2. Reported injury vs. no report of injury by sex. Values expressed as n (%).

Injury Group	**Total** (n=427)	**Females** (n=141)	**Males** (n=286)
Reported Injury	147 (34.4)	76 (53.9)	71 (24.8)
No Report of Injury	280 (65.6)	65 (46.1)	215 (75.2)

Table 5.3. Baseline characteristics of U.S. Army basic trainees at Fort Jackson, SC and differences between sexes. Values expressed as mean ± SD.

Characteristics	**Total** (n=427)	**Females** (n=141)	**Males** (n=286)	**Significance** (p-value)
Age (years)	21.43 ± 3.61	21.35 ± 3.50	21.46 ± 3.66	0.65
Height (cm)	171.63 ± 9.37	162.07 ± 6.28	176.34 ± 6.67	< 0.0001
Weight (kg)	73.55 ± 13.29	63.72 ± 8.57	78.40 ± 12.51	< 0.0001
Body Mass Index (kg/m^2)	24.87 ± 3.39	24.23 ± 2.66	25.19 ± 3.66	0.02
Body Fat Percentage (%)	26.15 ± 7.65	32.44 ± 5.43	23.05 ± 6.61	0.001
Bone Mineral Density (g/cm^2)	1.23 ± 0.13	1.17 ± 0.10	1.27 ± 0.12	0.03

Table 5.4. Baseline QSEBT normalized reach distances of U.S. Army basic trainees at Fort Jackson, SC and difference between sexes. Values expressed as mean ± SD in centimeters.

Reach Distance (cm) *Stance Leg*	**Total** (n=427)	**Females** (n=141)	**Males** (n=286)	**Significance** (p-value)
8-Composite*				
Dominant	78.79 ± 9.26	77.35 ± 8.70	79.50 ± 9.47	0.14
Non-Dominant	80.78 ± 9.39	78.95 ± 8.46	81.69 ± 9.70	0.04
3-Composite**				
Dominant	82.43 ± 10.28	79.86 ± 9.59	83.70 ± 10.39	0.09
Non-Dominant	84.38 ± 10.49	81.73 ± 9.34	85.68 ± 10.79	0.04

*The 8-direction composite score was an average of anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anterolateral directions.
**The 3-direction composite score was an average of the anterior, posterolateral, and posteromedial directions.

Table 5.5. Baseline WBLT distances from wall of U.S. Army basic trainees at Fort Jackson, SC and difference between sexes. Values expressed as mean ± SD in centimeters.

Extremity Tested	**Total** (n=427)	**Females** (n=141)	**Males** (n=286)	**Significance** (p-value)
Dominant	10.08 ± 3.72	9.88 ± 3.26	10.17 ± 3.92	0.03
Non-Dominant	9.89 ± 3.60	9.68 ± 3.14	10.00 ± 3.81	0.02

Table 5.6. Baseline number of successful trials of the SLWS of U.S. Army basic trainees at Fort Jackson, SC and difference between sexes. Values expressed as n (%).

Extremity Tested	**Total** (n=427)	**Females** (n=141)	**Males** (n=286)	**Significance** (p-value)
Dominant	268 (62.8)	91 (64.5)	177 (61.9)	0.60
Non-Dominant	265 (62.1)	93 (66)	172 (60.1)	0.25

Table 5.7. Baseline history questions of U.S. Army basic trainees at Fort Jackson, SC. Values expressed as n (%).

Question	Response Options	Total (n=427)	Females (n=141)	Males (n=286)
Have you ever played or participated in any sports/organized physical activity?	Yes	371 (86.9)	121 (85.8)	250 (87.4)
	No	56 (13.1)	20 (14.2)	36 (12.6)
Compared to others of the same age and sex, how would you rate yourself as to the amount of physical activity you performed prior to entering training?	Less active	166 (38.9)	70 (49.6)	96 (33.6)
	About the same	102 (23.9)	33 (23.4)	69 (24.1)
	More active	159 (37.2)	38 (27)	121 (42.3)
Over the last 2 months, prior to entering BCT, what was the average number of times per week you exercised or played sports for at least 30 minutes at a time?	< 1 time per week	90 (21.1)	31 (22)	59 (20.6)
	2-4 times per week	227 (53.2)	85 (60.3)	142 (49.7)
	> 5 times per week	110 (25.8)	25 (17.7)	85 (29.7)
How does your level of exercise over the past month compare to your exercise or sport frequency during the entire year prior to entering BCT?	Less	149 (34.9)	47 (33.3)	102 (35.7)
	About the same	135 (31.6)	44 (31.2)	91 (31.8)
	More	143 (33.5)	50 (35.5)	93 (32.5)
Over the last 2 months, prior to entering BCT, what was the average number of times per week you ran or jogged?	< 1 time per week	150 (35.1)	56 (39.7)	94 (32.9)
	2-4 times per week	239 (56)	76 (53.9)	163 (57)
	> 5 times per week	38 (8.9)	9 (6.4)	29 (10.1)
Over the last 2 months, prior to entering BCT, how often did you perform weight training exercises?	< 1 time per week	206 (48.2)	84 (59.6)	122 (42.7)
	2-4 times per week	171 (40)	52 (36.9)	119 (41.6)
	> 5 times per week	50 (11.7)	5 (3.5)	45 (15.7)

Table 5.8. Additional baseline history questions for female U.S. Army basic trainees at Fort Jackson, SC. Values expressed as n (%).

Question	**Response Options**	**Total** (n=141)
At what age did you have your first period?	< 10 years old	9 (6.4)
	10-12 years old	76 (53.9)
	13-15 years old	51 (36.2)
	> 15 years old	5 (3.5)
Over the last 12 months, how many menstrual periods have you had?	0-6	23 (16.3)
	7-9	18 (12.8)
	10-12	85 (60.3)
	≥ 13	15 (10.6)

Table 5.9. Mean normalized reach distances for QSEBT and mean distance from wall for WBLT in reported injury vs. no report of injury groups (n=427).

Physical Performance Test *Extremity Tested*	**Reported Injury** (n=147) (Mean ± SD) (cm)	**No Report of Injury** (n=280) (Mean ± SD) (cm)	**Significance** (p-value)
8-Composite*			
Dominant	77.66 ± 9.73	79.38 ± 8.97	0.22
Non-Dominant	79.69 ± 9.63	81.36 ± 9.22	0.56
*Difference****	3.65 ± 2.54	3.66 ± 2.79	0.76
3-Composite**			
Dominant	80.48 ± 10.46	83.46 ± 10.05	0.65
Non-Dominant	82.79 ± 10.63	85.21 ± 10.33	0.70
*Difference****	4.75 ± 3.91	5.41 ± 4.83	0.37
Weight-Bearing Lunge			
Dominant	10.14 ± 3.86	10.04 ± 3.64	0.39
Non-Dominant	9.99 ± 3.70	9.85 ± 3.56	0.78
*Difference****	1.44 ± 1.07	1.58 ± 1.47	0.84

*The 8-direction composite score was an average of anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anterolateral directions.

**The 3-direction composite score was an average of the anterior, posterolateral, and posteromedial directions.

***The difference was calculated as the absolute value of the difference between the measurements between extremities.

Table 5.10. Number of successful trials of the SLWS in reported injury vs. no report of injury groups (n=427). Values expressed as n (%) of successful trials*.

Single Leg Wall Squat	**Reported Injury** (n=147) (# of successful trials)	**No Report of Injury** (n=280) (# of successful trials)	**Significance** (p-value)
Dominant	87 (59.2)	181 (64.6)	0.27
Non-Dominant	90 (61.2)	175 (62.5)	0.80

* A successful trial is defined by the participant being able to hold the testing position for one minute.

Table 5.11. Final model following logistic regression analysis of 286 male basic trainees' injury incidence during BCT.

Predictor	**β**	**SE β**	**Wald's χ^2**	***p***	**e^{β} (Odds Ratio)**	**95% Wald Confidence Limits**
Intercept	0.396	1.165	0.115	0.734	NA	NA
3-Direction Composite QSEBT (Dominant)	-0.025	0.014	3.327	0.068	0.975	[0.949, 1.002]
WBLT (Non-Dominant)	0.069	0.038	3.332	0.068	1.072	[0.995, 1.155]
30 Minutes of Exercise in Days/Week (< 1 time)	0.634	0.216	8.642	0.003	1.884	[1.235, 2.875]
30 Minutes of Exercise in Days/Week (2-4 times)	-0.349	0.190	3.376	0.066	0.706	[0.487, 1.024]
30 Minutes of Exercise in Days/Week (> 5 times)	-0.285	0.213	1.784	0.182	0.752	[0.495, 1.142]

Test	**Wald's χ^2**	***p***
Likelihood Ratio Test	13.302	0.010
Score Test	13.603	0.009
Wald Test	12.885	0.012

Note: Levels of exercise in days/week were compared to the average of the rest of the participants' responses. Model Evaluation Measures: R^2 = 0.0454. Max-rescaled R^2 = 0.0674. Area under ROC curve = 0.636. Homer and Lemeshow Goodness-of-Fit Test: p = 0.534. NA = Not Applicable.

Table 5.12. Final model following logistic regression analysis of 141 female basic trainees' injury incidence during BCT.

Predictor	**β**	**SE β**	**Wald's χ^2**	***p***	**e^{β} (Odds Ratio)**	**95% Wald Confidence Limits**
Intercept	5.816	2.184	7.089	0.008	NA	NA
Bone Mineral Density	-5.009	1.863	7.234	0.007	0.007	[<0.001, 0.257]
30 Minutes of Exercise in Days/Week (< 1 time)	0.557	0.307	3.297	0.069	1.174	[0.957, 3.182]
30 Minutes of Exercise in Days/Week (2-4 times)	0.364	0.249	2.127	0.145	1.438	[0.883, 2.344]
30 Minutes of Exercise in Days/Week (> 5 times)	-0.920	0.340	1.326	0.007	0.399	[0.205, 0.776]

Test		**Wald's χ^2**	***p***	
Likelihood Ratio Test		16.391	0.001	
Score Test		15.476	0.002	
Wald Test		13.503	0.004	

Note: Levels of exercise in days/week were compared to the average of the rest of the participants' responses. Model Evaluation Measures: R^2 = 0.1097. Max-rescaled R^2 = 0.1466. Area under ROC curve = 0.6635. Homer and Lemeshow Goodness-of-Fit Test: p = 0.151. NA = Not Applicable.

Table 5.13. Final model following logistic regression analysis of 427 male and female basic trainees' injury incidence during BCT.

Predictor	**β**	**SE β**	**Wald's χ^2**	***p***	**e^{β} (Odds Ratio)**	**95% Wald Confidence Limits**
Intercept	4.212	1.604	6.890	0.009	NA	NA
Sex	0.889	0.241	13.673	0.0002	2.433	[1.519, 3.898]
Bone Mineral Density	-3.159	0.952	11.007	0.001	0.042	[0.007, 0.274]
3-Direction Composite QSEBT (Dominant)	-0.021	0.011	3.546	0.060	0.979	[0.958, 1.001]
30 Minutes of Exercise in Days/Week (< 1 time)	0.970	0.329	8.698	0.003	2.637	[1.384, 5.024]
30 Minutes of Exercise in Days/Week (2-4 times)	0.370	0.283	1.714	0.191	1.448	[0.832, 2.520]
30 Minutes of Exercise in Days/Week (> 5 times)	-1.340	0.550	5.930	0.015	0.262	[0.089, 0.770]

Test		**Wald's χ^2**	***p***	
Likelihood Ratio Test		59.075	<0.0001	
Score Test		57.329	<0.0001	
Wald Test		51.031	<0.0001	

Note: Male is referent level of sex. Levels of exercise in days/week were compared to the average of the rest of the participants' responses. Model Evaluation Measures: $R^2 = 0.1292$. Max-rescaled $R^2 = 0.1784$. Area under ROC curve = 0.7199. Homer and Lemeshow Goodness-of-Fit Test: p = 0.087. NA = Not Applicable.

Figure 5.1. Participant foot positioning for the QSEBT.

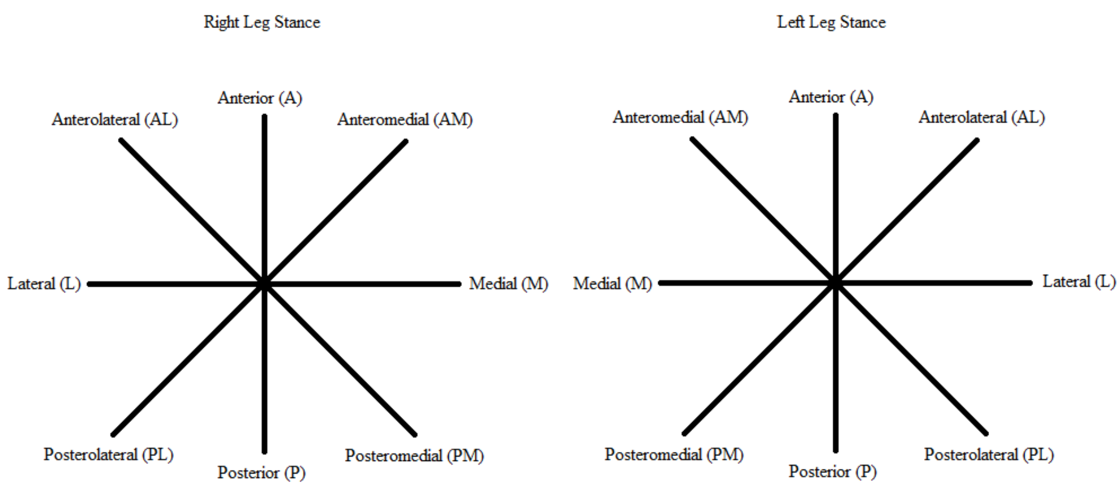

Figure 5.2. QSEBT reach directions for the left and right stance legs.

Figure 5.3. Leg length measurement (from anterior superior iliac spine to most distal lateral malleolus).

Figure 5.4. Participant positioning for the WBLT.

Figure 5.5. Knee flexion angle (60 degrees) for the SLWS confirmed using a goniometer (fulcum: lateral epicondyle of the femur, stationary arm: greater trochanter of femur, movement arm: lateral malleolus).

Figure 5.6. Participant positioning for the SLWS.

CHAPTER 6

OVERALL CONCLUSIONS

Preparation for military service requires consistent physical activity and exposure to repetitive stress, setting up basic trainees for musculoskeletal injury. Additional risk factors experienced by an individual basic trainee can increase incidence rates, such as sudden increases in physical activity,[8] poor range of motion and balance,[55] weak musculature,[6] and menstrual irregularities.[9,11-13] The severity of these injuries dictate the extent of lost training time,[16] the rate of basic trainee discharge,[17] and the financial cost to the U.S. Department of Defense.[2]

Efforts to identify musculoskeletal injury risk factors prior to beginning BCT are necessary to challenge the high incidence rates of injuries during training. Previous research has identified that measures of dynamic postural control,[20] ankle dorsiflexion,[68-70] and hip musculature dysfunction[72,73] can be associated with injury risk. Measures obtained from the QSEBT provide moderate to excellent inter-rater reliability in real-time when utilizing pieces of tape marked with centimeters and good to moderate test-retest reliability for the first successful trial in all 8 reach directions bilaterally. Averaging only 3 minutes and 38 seconds per participant, researchers and clinicians can utilize the QSEBT quickly to assess dynamic postural control as a baseline measure.

While initial findings using self-report of injury measures imply that the QSEBT may contribute to the identification of basic trainees at a higher odds of injury during BCT, future study must examine the predictive validity of the measures of the QSEBT, WBLT,

and SLWS on diagnosed injuries from a medical provider, injuries that require basic trainees to not participate in training, and attrition from BCT. Analyses of diagnosed injuries, lost time, and attrition rates will provide a greater understanding of the predictive validity of the physical performance tests and their usefulness for large-scale application for physically active populations.

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APPENDIX A

PAR-Q AND AHA/ACSM HEALTH/FITNESS FACILITY PRE-PARTICIPATION SCREENING QUESTIONNAIRES

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ________________________________

SIGNATURE ________________________________ DATE ________________________

SIGNATURE OF PARENT ________________________ WITNESS ________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health needs by marking all *true* statements.

History

You have had:

___ A heart attack
___ Heart surgery
___ Cardiac catheterization
___ Coronary angioplasty (PTCA)
___ Pacemaker/implantable cardiac defibrillator/rhythm disturbance
___ Heart valve disease
___ Heart failure
___ Heart transplantation
___ Congenital heart disease

If you marked any of the statements in this section, consult your physician or other appropriate healthcare provider before engaging in exercise. You may need to use a facility with a ***medically qualified staff****.*

Symptoms

___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, blackouts.
___ You take heart medications.

Other health issues

___ You have diabetes
___ You have or asthma other lung disease.
___ You have burning or cramping in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity.
___ You have concerns about the safety of exercise.
___ You take prescription medication(s).
___ You are pregnant.

Cardiovascular risk factors

___ You are a man older than 45 years.
___ You are a woman older than 55 years, you have had a hysterectomy, or you are postmenopausal.
___ You smoke, or quite within the previous 6 mo.
___ Your BP is greater than 140/90.
___ You don't know your BP.
___ You take BP medication.
___ Your blood cholesterol level is >200 mg/dL.
___ You don't know your cholesterol level.
___ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
___ You are physically inactive (i.e., you get less than 30 min. of physical activity on at least 3 days per week).
___ You are more than 20 pounds overweight.

If you marked two or more of the statements in this section, you should consult your physician or other appropriate healthcare provider before engaging in exercise. You might benefit by using a facility with a ***professionally qualified exercise staff*** *to guide your exercise program.*

___ None of the above is true.

You should be able to exercise safely without consulting your physician or other healthcare provider in a self-guided program or almost any facility that meets your exercise program needs.

Balady et al. (1998). AHA/ACSM Joint Statement: Recommendations for Cardiovascular Screening, Staffing, and Emergency Policies at Health/Fitness Facilities. *Medicine & Science in Sports & Exercise, 30*(6). (Also in: *ACSM's Guidelines for Exercise Testing and Prescription*, 7th Edition, 2005. Lippincott Williams and Wilkins http://www.lww.com)

www.acsm-msse.org/pt/pt-core/template-journal/msse/media/0698c.htm

APPENDIX B

INSTRUCTIONS FOR THE QUICK STAR EXCURSION BALANCE TEST

Please take off your shoes and socks.

[RESEARCHER WILL DEMONSTRATE WHILE READING INSTRUCTIONS]

The Quick Star Excursion Balance Test measures the stability of your leg musculature and core. You will stand in the middle of the grid on one foot and will be reaching as far as you possibly can along each of these eight lines with your other foot while maintaining balance on your stance leg. You will make a light touch with your toes on the line and return back to a double leg stance at the center, maintaining balance the entire time. Do not transfer weight with the light touch or allow the contact to affect your overall balance. When crossing your body, you must reach behind your stance leg.

If I determine that you use your reaching leg for a substantial amount of support at any time or if you lose balance on the stance leg throughout the test, the trial must be repeated. You must also keep your stance foot at the center of the grid.

We will measuring how far you are able to reach and still performance the test correctly.

Correct performance is important. What questions do you have?

APPENDIX C

DATA COLLECTION RECORDING SHEET FOR AIM ONE

Quick Star Excursion Balance Test: (ROUND 1) **TIME: ___________ sec**

LEFT Leg Stance: A: ____ cm AL: ____ cm L: ____ cm PL: ____ cm

P: ____ cm PM: ____ cm M: ____ cm AM: ____ cm

RIGHT Leg Stance: A: ____ cm AL: ____ cm L: ____ cm PL: ____ cm

P: ____ cm PM: ____ cm M: ____ cm AM: ____ cm

Quick Star Excursion Balance Test: (ROUND 2) **TIME: ___________ sec**

LEFT Leg Stance: A: ____ cm AL: ____ cm L: ____ cm PL: ____ cm

P: ____ cm PM: ____ cm M: ____ cm AM: ____ cm

RIGHT Leg Stance: A: ____ cm AL: ____ cm L: ____ cm PL: ____ cm

P: ____ cm PM: ____ cm M: ____ cm AM: ____ cm

Weight-Bearing Lunge Test: **TIME: ___________ sec**

RIGHT: ______ cm LEFT: ______ cm

APPENDIX D

INSTRUCTIONS FOR THE WEIGHT-BEARING LUNGE TEST

Please keep off your shoes and socks.

[RESEARCHER WILL DEMONSTRATE WHILE READING INSTRUCTIONS]

The Weight-Bearing Lunge Test measures the flexibility of the back of your lower leg and the range of motion of your ankle. You will begin in a lunge position facing the wall. The goal is to lunge forward and touch the wall with the kneecap of your lead leg while keeping the heel of the same foot on the ground.

We will be measuring how far away from the wall you are able to get your foot and still perform the test correctly.

Correct performance is important. What questions do you have?

We will start with your right leg.

APPENDIX E

INSTRUCTIONS FOR THE SINGLE LEG WALL SQUAT

[RESEARCHER WILL DEMONSTRATE WHILE READING INSTRUCTIONS]

The Single Leg Wall Squat measures the endurance and strength of the muscles of the legs and core. On the command, “get set,” you will assume a single leg wall squat position. Your knee must be bent to 60 degrees, and I will confirm that for you. You opposite leg must be lifted from the ground and your arms will be paced in an “X” pattern across your chest.

Upon confirmation of the correct amount of knee bend, I will start the timer. You will be asked to maintain this position, holding your body in a generally rigid state, for as long as possible, up to one minute.

The test will be terminated if you change the amount of knee bend, bend at the wait, uncross your arms, or touch your lifted foot to the ground.

Correct performance is important. What questions do you have?

We will start with your right leg. Remember to hold this position as long as you can.

APPENDIX F

DATA COLLECTION RECORDING SHEET FOR AIM TWO

Quick Star Excursion Balance Test

Leg Dominance: **RIGHT** **LEFT**

Right Limb Length: ___________ cm

Left Limb Length: ___________ cm

RIGHT Leg Stance: A: ____ cm AL: ____ cm L: ____ cm PL: ____ cm

P: ____ cm PM: ____ cm M: ____ cm AM: ____ cm

LEFT Leg Stance: A: ____ cm AL: ____ cm L: ____ cm PL: ____ cm

P: ____ cm PM: ____ cm M: ____ cm AM: ____ cm

Weight-Bearing Lunge Test

RIGHT: ______ cm

LEFT: ______ cm

Single Leg Wall Squat

RIGHT: **YES** **NO** Time: _______________

LEFT: **YES** **NO** Time: _______________

APPENDIX G

DISCLAIMER

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