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The Effects Of External Load And Body Composition On The Sebt In Marching Band Performers

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ABSTRACT

Introduction: Marching band performers are susceptible to a variety of injuries that may have long-term consequences, especially in the lower extremity. The Star Excursion Balance Test (SEBT) dynamic stability assessment tool has been utilized to detect the risk of lower extremity injuries, such as chronic ankle instability. The SEBT may be influenced by internal and external load variations amongst individuals; however, the interactions between these factors and the impact on specific populations, such as marching band performers, have not been studied. Therefore, the purpose of this study is to determine how performance on the SEBT differs when taking external load from instruments and body composition into account in marching band performers. **Methods**: Height, weight, leg length, and body composition via DEXA Scan were obtained during each initial visit. During the second visit, the subject completed the SEBT with and without carrying various musical instruments bilaterally. **Results**: There were 31 participants in the study, 3 participated solely in the body composition portion of the study, 1 only participated on the SEBT, and 27 participated in the entire study. The participant's age (19.67±1.74 years), height (169.72±10.46 cm), weight (81.73±19.96 kg), total mass (80.75±20.51 kg), fat mass (29.59±12.47 kg), lean mass (48.58±10.50 kg), fat-free mass (51.16±10.95 kg), bone mineral density (1.23±0.12 g/cm^2), bone mineral content (2.58±0.49 kg), and relative skeletal muscle mass (7.62±1.46 kg/m^2) were all measured. Total mass had the most amount of significant correlation with lower reach scores. The tenor drums were found to significantly lower reach distances compared to all other conditions in each reach direction and stance limb ($p \leq 0.05$). There were no significant symmetrical differences in reach scores when loaded ($p \geq 0.05$). **Conclusion**: Wearing the tenor drum significantly decreases performance on the SEBT. Future investigations should look at the prevalence of lower extremity injuries in tenor drum players in relation to the SEBT to help determine at-risk performers. External load did not reveal significant asymmetrical differences in reach scores when compared to unloaded scores. All variables of body composition, especially total mass, have correlations with lower reach scores.

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I. Introduction

Marching band performers are susceptible to acute and chronic injury similar to participants of any sport. When compared to collegiate level athletes, collegiate marching band performers do not have the same level of fitness but still require a degree of physical fitness to perform their activity. Although there is limited clinical research that has investigated this population, it has been found that the lower extremity is the most injured region in band performers with the ankle sustaining most of these injuries.[2,25] This could be due to the high levels of force that the body must attenuate while marching. Depending on where the performers are marching, surface design can influence the ankle's kinematic and kinetic motions thus making certain muscles of the lower leg work harder; exposing them to possible fatigue.[11] When the lower leg becomes fatigued, the stability of the ankle diminishes and can increase the risk of injury. Repetitive marching accelerates fatigue of the peroneus longus muscle, which is a dominant cause for lack of foot stability, manifesting in abnormal center of pressure deviations causing a reduction in foot stability.[11] This increases the risk of ankle sprains, subtalar instability, tendonitis, and stress fractures.[1]

Chronic Ankle Instability

When sustaining an ankle sprain, damage is caused to the ligament structures that assist in stabilizing the ankle. The body attempts to repair the damaged structures, by initially laying down type III collagen which is thinner than the type I college that is found in non-damaged ligament.[53] Continuous sprains or inadequate healing of these ligaments can lead to this alteration of structural integrity which can thus make the patients develop chronic ankle instability (CAI).[28, 31, 44] CAI is characterized by laxity, and mechanical and functional instability of the ankle joint which can interfere with activity. [28, 31, 43] Studies have shown that individuals who have a history of lateral ankle sprains have a 70% chance of developing CAI.[31] It has also been observed that there is a 40% chance CAI can develop in individuals with a first-time lateral ankle sprain. [44] However, there is no guarantee that a single ankle sprain will result in CAI.

There are a multitude of assessment instruments that may be utilized to determine if a patient has CAI. [6,12,32,45-49] One commonly employed test is the star excursion balance test (SEBT), which is a clinical assessment tool that evaluates the lower extremity for dynamic balance deficits.[13,23] The SEBT assesses an individual's flexibility, strength, neuromuscular control, range of motion, and proprioception.[13] Additionally, asymmetry in reach scores has been associated with risk of injury in athletes.[13] Plisky et al. found that in high school basketball players, players whose left to right anterior reach distances were 4 cm or greater were 2.5 times more likely to sustain a lower extremity injury.[22] Plisky et al. also saw that having a composite reach distance less than 94.0% of their stance limb length were 6.5 times more likely to have a lower extremity injury (P<.05).[22] Butler et al. found that college football players who had a composite score below 89.6% based on their limb length were 3.5 times more likely to get injured.[54]

The SEBT has been shown to reliably predict the risk of lower extremity injury and identify dynamic balance deficits in patients with a lower extremity injury. [13, 20, 22,

[24] It has also been shown to have discriminant validity when comparing healthy individuals to individuals with lower extremity pathologies. [1,15]

There are two methods of conducting the SEBT. The traditional SEBT requires the patient to balance on one leg (stance leg) and perform a single leg squat while reaching as far as possible in eight different directions with the opposing leg (anterior, anteromedial, medial, posteromedial, posterior, posteromedial, posterolateral, lateral, and anterolateral) where each direction is 45° apart.[13,19] The modified star excursion balance test (mSEBT) requires the patient to reach in three directions (anterior, posteromedial, and posterolateral) where there is a 135° separation from the anterior line to the posterior directions and 90° separation between the posteromedial and posterolateral direction.[19,24] The mSEBT has been often utilized over the traditional SEBT because the anterior, posteromedial, and posterolateral reaches are the directions most associated with injury.[14,24]

The majority of the research that uses the SEBT as an assessment tool that looks at the effectiveness of the SEBT has been conducted in athletes. There has been no investigation looking at the normative values of the SEBT in marching band performers. Additionally, no research has examined the effectiveness of the SEBT as a predictor of lower extremity injury in these performers. The level of physical activity that marching band performers participate in is not as intensive as levels seen in other sports; however, it carries many of the same risks. It requires strength, flexibility, endurance, and motor control to march effectively and efficiently. Thus, a maneuver such as the SEBT may have the benefit of detecting dynamic balance impairments in marching band performers that could lead to injury.

Body Composition and Instrument External Load

In addition to structural impairments, obesity has been linked to an increased risk of lower extremity injuries in this population. [35-42] There is a correlation between individuals with high body mass indexes and lower extremity injuries. [35-37,39-41] These injuries include ankle sprains, ligamentous knee injuries, and chondral injuries. A reason for this increase in injury is due to the increased load on the lower extremity joints and alterations in ambulation and gait biomechanics caused by aberrant weight distribution. [40]

When band performers march, they do so with their equipment adding an additional load to their body. The varying weights of these loads and where the loads are positioned may contribute to injury risk along with body composition. For example, the effects of the extra load of a clarinet adds approximately one pound to the performer which is vastly different from the load a sousaphonist may experience, which is approximately an extra 30-35 lbs. The placement of these loads may potentially cause alterations in stability. When comparing a sousaphonist to a performer who plays the tenor drums (30-45 lbs) they both have a similar external load added to them, but the positioning of these loads differs which could alter various aspects of biomechanics. For example, there is an overhead and axial load that is added to the sousaphonist, whereas the tenor drum performer's load is mainly displaced anteriorly. This alters both kinematics of various joints and the center of gravity for the entire musculoskeletal system. Additionally, the individual's body size relative to the instrument's weight and size can be a variable that can have the potential to increase the risk of sustaining a lower extremity injury.[51]

The interaction and impact of dynamic postural deficits, body composition, and external load on injury history or risk have not been fully elucidated in the literature. The SEBT is a functional test and clinicians should take all of these factors into consideration when conducting the assessment. Each one of these factors can cause alterations to one's postural control and biomechanical function. However, few investigations have shown the effects that external loads from sports equipment have on dynamic postural control as seen through the SEBT. The few studies that have been conducted demonstrate that external loads decrease performance on the SEBT; although it has yet to be determined if the external load can cause asymmetries in reach distances that would not regularly appear when completing the SEBT without an external load.[6,33]

Furthermore, to our knowledge, no investigation has looked at how well the SEBT is as a predictor of injury in marching band performers or how external load from instruments may alter performance when utilizing the SEBT as a functional assessment tool. The SEBT has the capability of giving athletic trainers and other clinicians working with the marching band performers a preseason screening assessment tool to know which performers may be at risk of lower extremity injuries.

Therefore, the purpose of this study is to examine how body composition and external load from an instrument impact dynamic postural control measures using the SEBT in marching band performers. It is predicted that there will be a ≥ 4% reduction in composite reach distances when taking external loads into account. It is also predicted that having external loads while performing the SEBT will be able to portray significant asymmetrical reach distances that are not seen be unloaded. When assessing the impact of body composition on the SEBT reach distance, it is hypothesized that higher total mass and fat mass will be significantly correlated with lower reach scores on the SEBT, while fat-free mass, lean mass, and the relative skeletal mass index will be significantly correlated to having lower reach scores.

II. Literature Review

Marching band performers are susceptible to both acute and chronic injury just like other participants in physical activities. Though their level of activity does not predispose them to an equal rate of injuries as their athletic counterparts, marching requires fitness and many of the physiologic properties of other sports to keep this population from injury. The injuries that are commonly found in this population are lower extremity injuries with the ankle found to be the most frequently injured body region.[2,25] The reason for this can be due to the repetitive dynamic impact on the lower extremity during marching.[2] Gefen et al. found that the peroneus longus and the gastrocnemius fatigued within 10 minutes of marching.[11] Repetitive marching accelerates fatigue of the peroneus longus muscle, leading to a lack of foot stability that could manifest in abnormal center of pressure deviations that result in a reduction in foot stability.[11] This could increase the risk of ankle sprains, subtalar instability, tendonitis, and stress fractures.[11]

Chronic Ankle Instability

Acute ankle sprains are the most common musculoskeletal injury, with there being an estimated 2 million cases each year in the United States.[28] Half of all ankle sprains treated by the emergency department are sustained by non-athletic activity.[30] Regardless of the level of sport participation, acute ankle sprains occur at high rates. Acute ankle sprains account for about 15% of all injuries sustained during sport participation at the high school and collegiate team sports.[28] In the NBA, on average

26% of players sustain an ankle sprain each season.[29] Individuals who have a history of ankle sprains are 3.5 times more likely to sustain future ankle sprains than individuals with no history.[28]

When someone sustains an ankle sprain the ligamentous structures that stabilize the ankle become stretched and damaged.[44] When healing the body lays down type III collagen fibers, it is thinner than the type I fibers that are most abundant in these structures prior to injury.[53] Up to 70% of these individuals can develop a residual physical disability, such as chronic ankle instability.[28] Chronic ankle instability (CAI) occurs when there is chronic insufficiency of the lateral ligament complex in the ankle.[28] Hertel et al. characterized CAI as being more than 12 months removed from an initial lateral ankle sprain and exhibiting a propensity for recurrent ankle sprains, frequent episodes or perceptions of the ankle giving way, and persistent symptoms such as pain, swelling, limited motion, weakness, and diminished self-reported function.[44] Individuals with a history of lateral ankle sprains have a 70% chance of developing CAI shortly after the initial injury.[28,31] Additionally, there is a 40% chance individuals can develop CAI after a first-time lateral ankle sprain.[44] Individuals with a history of lateral ankle sprains or CAI can develop post-traumatic osteoarthritis due to the changes in arthrokinematics motions caused by the instability. When evaluating individuals with CAI or a history of ankle injuries it is crucial to have an assessment tool to help distinguish differences in ankle stability in a variety of populations.

Star Excursion Balance Test

The star excursion balance test (SEBT) is a clinical assessment tool that allows clinicians to assess an individual's lower extremity dynamic balance. It requires the person to utilize flexibility, strength, neuromuscular control, core stability, range of motion, and proprioception.[13, 23] It is commonly used to assess athletes with chronic ankle instability and other lower extremity conditions.[1,4-5,7-8,10,12-16,19,21-22,24,23-27]

Athletic tape is commonly used to create the "star" of the SEBT (Figure 1). A star (similar to an asterisk) is made using four pieces of athletic tape (6 to 8 ft. long) where the tape overlaps each other making a "+" and "X".[17, 21] These eight points are required to be 45° apart from one another.[19] The eight directions are anterior, anteromedial, medial, posteromedial, posterior, posteromedial, posterolateral, lateral, and anterolateral.

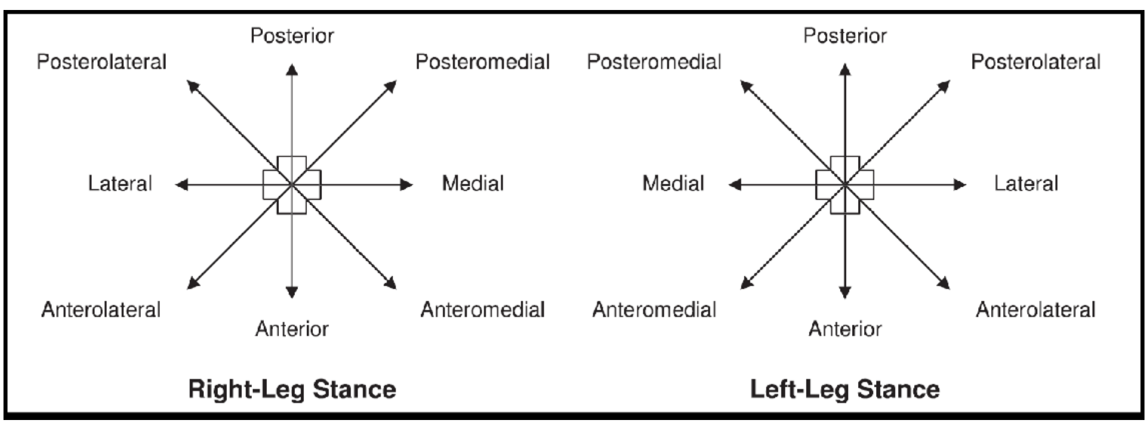

Figure 1. Directions of the Star Excursion Balance Test.[13]

There is a modification of the SEBT that is commonly used, which uses three of the eight directions (Figure 2). It has been shown that the anterior, posteromedial, and posterolateral directions are the ones that are mostly associated with injury risk.[13,14,24] The modified star excursion balance test (mSEBT) follows a similar setup but is "Y" shaped instead of a star. The distance between the anterior direction to the posterolateral and posteromedial are required to be 135° apart.[24] The posteromedial and posterolateral are required to be 90° away from each other.[19,24]

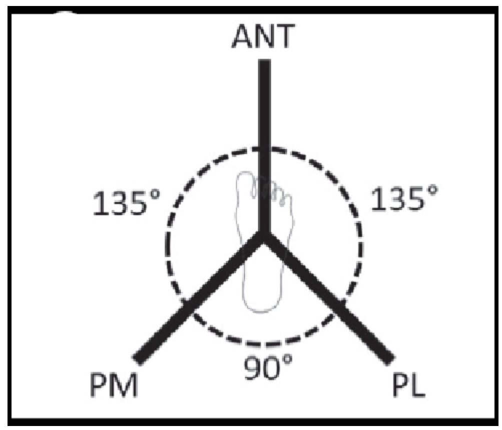

Figure 2. The modified Star Excursion Balance Test for the Right Leg.[24]

In both versions, the test requires patients to stabilize on one leg and use the contralateral leg to maximally reach toward the designated directions.[13] The placement of the foot varies. The foot can be positioned in front or behind the interception of each direction, or the foot can be placed in the center of where the tape intersects.[24] It has been suggested to use the changing alignment position method, which requires the patient to place their toe on the zero points when reaching anteriorly and place their heel at zero when reaching towards the posterolateral and posteromedial direction.[5] The reason for this is so that foot size does not cause large differences when collecting data.[5] To normalize reach distances hands should be kept on the hips and the heel of the individual should remain flat on the ground.[5, 24] Before being tested, the clinician should allow the patient to complete four practice trials to allow for more consistent results.[13, 20, 24] After completing the practice trials, the patients are then instructed to complete the SEBT three times. This test is then completed again on the opposite leg. If the subject loses balance, rests their lifted foot on the ground, or is unable to return to the starting position under control then their trial would be nullified.

A composite score is then calculated for each direction, and the scores are compared bilaterally. The normative values of this test vary for each population and further research must be conducted to find them.[13] The reach distances are measured in centimeters and normative values can vary depending on the person's height and leg length.[19, 24] To normalize values and assess performance, excursion distance is divided by leg length and multiplied by 100.[19, 20,55]

$$\frac{Excursion\ Distance}{Leg\ Length} \times 10$$

Before testing it is important to inquire if the patient has a history of lower extremity injury or CAI. Having a history of a lower extremity injury can cause large discrepancies when recording reach distances. When assessing someone that has CAI or a lower extremity injury, reach distances on the SEBT typically score lower when compared to the uninjured limb or healthy individuals.[23] Furthermore, individuals with anterior ligamentous laxity have been known to have deficits in functional performance tests such as the SEBT.[27]

The SEBT is a sensitive, highly representative, non-instrument dynamic balance test for physically active individuals and can help recognize a multitude of functional deficits by assessing if the patient has asymmetrical deficits or a reduction in normalized reach distances.[13,19,22,54] The SEBT can be utilized to distinguish dynamic balance deficits in patients with lower extremity conditions.[13] It can help identify deficits in patients with chronic low back pain, knee osteoarthritis, patellofemoral pain syndrome, bilateral neuromuscular control deficits, and chronic ankle instability.[8,10,13,16,19] In a study done on high school basketball players, Plisky et al. found that having a 4cm or greater anterior reach distance compared bilaterally were 2.5 times more likely to sustain a lower extremity injury.[22] Plisky et al. also saw that having a composite reach distance of less than 94.0% of their stance limb length were 6.5 times more likely to have a lower extremity injury ($P<.05$).[22] In another study, Butler et al. noted that college football players who has a composite score below 89.6% based of their limb length were 3.5 times more likely to get injured.[54]

SEBT Reliability and Validity

Research has shown that the SEBT is a reliable measure in predicting the risk of lower extremity injury and identifying dynamic balance deficits in individuals with lower extremity conditions.[13,20,22,24] Powden et al. conducted a systematic review which found the SEBT to have excellent inter-rater reliability (ICC=0.83-0.96, 0.80-1.00, and 0.73-1.00 for anterior, posteromedial, and posterolateral directions respectively) and intra-rater reliability (ICC=0.84-0.93, 0.85-0.94, and 0.68-0.94 for anterior, posteromedial, and posterolateral directions respectively) in healthy adults.[24] As mentioned before there are numerous ways the SEBT can be conducted. It can be assumed that these alterations to this test can change its reliability. However, body positioning, such as starting foot position, has been shown to have no significant effect on the SEBT's intra- or inter-rater reliability.[24]

Aside from being a reliable functional test for lower extremity dynamic balance, the SEBT has various forms of validity depending on the population and how it is utilized. This test has high concurrent validity with the Optotrak (a visual camera system with high validity and excellent reliability) (ICC=0.99).[1] The SEBT was also shown to have discriminant validity between healthy individuals and individuals with lateral ankle sprains (5.11% to 8.63% differences between healthy individuals and individuals with lateral ankle sprains) and CAI ($P<0.05$ when comparing involved and uninvolved limbs during the posteromedial reaches).[1, 15]

Muscles Utilized During the SEBT

When performing the SEBT, numerous muscles engage to help the individual reach as far as possible without losing stability. Postural stability during the SEBT is highly dependent on the activation level of the tibialis anterior and peroneus brevis.[17] A closed kinetic chain (CKC) is used during postural stability, which requires the co-contraction between agonist and antagonist stabilizing muscles.[9] Earl et al. conducted a study where they looked at the lower extremity muscle activity during the SEBT.[9] It was shown that co-contraction between the hamstrings and quadriceps occurs in all directions. The quadriceps are highly active during the anterior movements. The vastus lateralis was highly active during the medial and posteromedial reaches, and the biceps femoris was highly active during the lateral and posterolateral excursion. Lastly, there were no significant changes in gastrocnemius activity during the different movements of the SEBT. This study helps show that muscle activity during this test is direction dependent.[3,9]

Another study by Bhanot et al. looked at the hip and trunk muscle activity during the SEBT with an electromyography (EMG).[3] It was found that all hip and trunk muscles were activated during the eight directions of the test. However, it was shown that certain muscles were highly activated more than others when reaching in certain directions. The following muscles had the most activity in the corresponding directions: ipsilateral external oblique was highly activated during the anterolateral reach; the contralateral external oblique was highly activated during the medial reach; the ipsilateral rectus abdominis was highly activated during the anterior reach; the contralateral rectus abdominis was highly activated during the anteromedial reach; the ipsilateral erector spinae was highly activated during the posterolateral reach; the contralateral erector spinae was highly activated during the posteromedial reach; the gluteus maximus was highly activated during the posterior reach; the gluteus medius was highly activated during the medial direction reach.[3] Weakness, inhibition, and damage to these structures can cause great limitations in performance during the SEBT.

SEBT Functional Replication

When assessing a patient's functionality, it is common for the clinician to test them in the clinic in the way they came dressed. However, this does not truly depict what is seen in their sport. When assessing functionality, the assessments should be conducted in a condition that will replicate where an athlete/performer will practice and play. If there are differences in load and how it impacts the detection of deficits, then we must test under "playing" conditions.

No research has taken external loads from marching band instruments into consideration when utilizing the SEBT. Denehey et al. conducted a study observing how the impact of an external load from football equipment impacted dynamic balance when using the mSEBT as an assessment tool.[6] The subjects (Division III college football players) in this study were required to be tested twice, once with the external load from their football equipment (6.2kg) and another time with no load. The results from this study showed that the external load from the football equipment significantly reduced posterolateral and anterior reach distances on the mSEBT. There were no significant differences found in the posteromedial reach distance. However, this study failed to complete the mSEBT correctly. The author of this study incorrectly labeled the reach distances and had the right leg stance directions labeled the same as the left leg stance causing the posteromedial and the posterolateral directions to be in the inappropriate areas. This means when completing their data analysis, the authors were comparing the left leg posteromedial reach score with the right leg posterolateral reach score which could have been a variable as to why they found no significant difference in reach scores for the posteromedial reach.

Ozunlu et al. conducted a similar study where they wanted to see how adolescent basketball player's dynamic postural control may be affected by external loads.[33] The participants were required to wear a backpack that was 20% of their body mass. This study used the traditional SEBT to assess dynamic postural control and revealed that when reaching toward the posteromedial direction there was a moderate effect size (Cohen d=0.67, 95% CI 5 0.02, 1.29). However, the performance in the other 7 directions showed that the extra mass did not significantly affect performance.

Although these two studies had contrasting findings, what they shared in common is that external load seems to have some sort of effect on dynamic balance. The differences in these findings can be contributed by several variables, such as weight distribution (vertical load vs posterior load), load weight ratios (6.2kg vs 20% of body weight), and differences in populations (Division III football players vs adolescent basketball players).

Effects of Load on Body

There is an array of instruments that performers play in a marching band. The weight of and posture to play an instrument varies. For instance, the piccolo's average weight is 1.25 pounds whereas sousaphones weigh 30 to 35 pounds; students carrying these instruments experience different kinematic and kinetic loads that may impact injury risk. The drumline is a section that one should take note of because their instrument adds an anterior load to the performer. The auxiliary equipment weight can range from 10 to 45 pounds. This anterior load may cause the performer to highly engage their trunk extensors. Having these muscles activated for long periods could cause them to become overactive and may cause changes along their kinetic chain. In addition, when the performers march backward, they have to keep their feet plantar flexed causing their gastrocnemius and peroneus longus to become highly active. As seen in Gefen et al. study, fatigue to these structures causes an increase in injury risk.

Furthermore, load carriage has been shown to have a negative impact on physiological attributes, but these effects change depending on how the load is distributed around the body.[52] External load effects on one's biomechanics can be greatly influenced by the performer's size relative to the instrument’s mass. Unnikrishnan et al. investigated the effects of body size and load carriage on lower-extremity biomechanical responses in healthy women. It was found that the smaller to medium-sized subjects had an increase in tibial strain and an alteration to joint mechanics when running with a 22.7 kg load.[51] This is significant because marching band performers who are of smaller stature carrying a large load may be subject to similar lower-extremity biomechanical stresses similar to individuals from this study.

Body Composition and Risk of Injury

Many of these performers who have a higher body mass or BMI are more susceptible to musculoskeletal injuries.[2] Obesity is associated with numerous comorbidities. There is a linear dose-response relationship with injuries among adults with a greater BMI.[41] Studies have suggested that individuals with higher body mass index (BMI) have an increased risk of injuries such as ankle injuries (mostly sprains), knee injuries, and concomitant chondral and ACL injuries.[42] Beckett et al. conducted a study and suggested that performers in marching band and color guard with increased BMI were more likely to have musculoskeletal injuries.[2] Fousekis et al. conducted a study where they analyzed risk factors for ankle injuries in 100 professional soccer athletes.[37] This study was able to determine that increases in body mass or BMI raised the tendency for acute ankle sprains.[37] In runners, overweight individuals sustain a higher rate of lower leg injuries when compared to normal weight runners.[38] In the U.S. Army soldiers with the highest BMI during accession had a higher rate of musculoskeletal injury.[39] Obesity has been linked to predisposing individuals to lower extremity overuse injuries because of the increase in load-bearing and the abnormal weight distribution that causes alterations to gait biomechanics.[40] Weight loss within individuals who have higher BMI exhibited a decrease in injury risk.[41]

In addition to musculoskeletal injuries, BMI has been linked to altered gait mechanics and falls.[34] According to Neri et al. and eagle et al., body mass and BMI can be utilized as a predictor of ankle injuries such as lateral ankle sprains.[35,36] Obesity has been associated with altered plantar pressure during gait.[34] The increase in load to the feet increases the risk of falling.[34]

It is clear that load carriage has a negative impact across a wide range of physiological and performance attributes, although that reduction cannot solely be explained on the basis of mass. Indeed, it is also related to the system of load carriage and how the load is distributed around the body. It is unclear, however, how external loads from instruments affect performance on the SEBT. As aforementioned, asymmetrical reaches on the SEBT can be an indicator of potential lower extremity injuries.[13,22,54] Perhaps when unloaded, the individual that is being tested on the SEBT demonstrates no asymmetries but demonstrates asymmetries when caring a load. If this situation proves to be true, the clinician would have never known that their patient is at risk. Furthermore, load carriage to body mass ratio is another factor that can contribute to an increased risk of lower injury.

In summary, the SEBT is a functional dynamic balance assessment tool that has high reliability and validity.[1, 4, 13, 15,20,22,24] It assesses an individual's flexibility, strength, neuromuscular control, core stability, range of motion, and proprioception.[13,23] It has been commonly used to assess physically active individuals who may be healthy or have a history of lower extremity injury. Based on what is known and what is not known, investigations should be performed to determine how SEBT results may vary when taking external loads (that represent the load the performer will carry) into account. Investigations should see if this load causes a significant reduction in reach scores and reveals asymmetries that were not present with the load but revealed when loaded. Load to body mass ratio should also be observed to see if this ratio leads to an increased risk of lower extremity injury. Lastly, studies should see how body mass affects performance on the SEBT in marching band performers. These findings could prove to be useful for athletic trainers or other clinicians working with this population in understanding how these factors affect performance on the SEBT and its potential to utilize it as a pre-season screening tool for injury risk or as a functional assessment for return to performance.

III. Methods

Participants

For this study, healthy, marching band performers between the ages of 18-35 were recruited to participate. The performers received an invitation to participate in a study where their body composition and performance on the mSEBT in multiple conditions would be analyzed (Appendix A). Each student's weight and body composition were measured using the Tanita (Appendix B) and the university-owned dual-energy X-ray absorptiometry (DEXA) scanner (Appendix C). Subjects were excluded if they had a current lower extremity injury, had lower extremity surgery within the past 6 months, were unable to perform their activity completely because of an injury, had a bodyweight exceeding 350 lbs (due to machine restrictions), did not participate in marching band, or a woman who was pregnant.

Testing Protocol

Prior to recording any data, each subject signed an informed consent document (Appendix D), which outlined the study's goals and purposes, a DEXA waiver (Appendix E), and screened for any factors that would have excluded them from the study. The screening was conducted by the principal investigator who was a certified athletic trainer. Each subject was given a packet that included patient-reported outcome measures and forms for testers to record data. Each subject completed an orthopedic injury history form, Foot and Ankle Disability Index (FADI) (Appendix F), FADI Sport (Appendix F), and Lower Extremity Functional Scale (LEFS) (Appendix H) to determine their self-reported level of lower extremity function.

Height and leg length was measured in centimeters. Leg length was measured from the anterior superior iliac spine to the ipsilateral inferior pole of the medial malleolus. Before measuring body weight and body composition, the subject was asked to remove their shoes, socks, and all metal jewelry. Prior to getting scanned, subjects were weighed on the Tanita scale to determine initial body weight. Body type, height, biological sex, and age on the Tanita scale were inputted for each subject. Once this is completed the subject was asked to step on the Tanita scale to measure their body weight. The recorded data (containing the subject’s body weight, fat mass percentage, lean mass percentage, etc.) was then printed by the Tanita and attached to the subject’s data packet. The subject was then asked to step off the scale.

After taking these measurements, the subject’s body composition was measured using the DEXA scanner. Participants were asked to wear tight-fitting clothing so that the device could accurately assess body composition. Subjects were then asked to lie supine on the DEXA scanner. The subjects were required to lay as still as possible, have their arms and hands by their sides, and keep their eyes closed. The scanning process, which can take 10 to 20 minutes (depending on the size of the subject), was conducted by certified personnel. Two scans could be required for larger subjects so both sides of the body can be effectively analyzed. Bone mineral density, total mass, fat mass, lean mass, bone mineral content, and relative skeletal muscle index were analyzed using the DEXA and recorded into the data packet.

The mSEBT was used to assess each subject's dynamic postural stability. The mSEBT was conducted under five different conditions per subject (holding no instrument, holding a baritone, holding a sousaphone, holding a tenor drum, and holding a tenor saxophone). Athletic tape was used to make each of the directions of the mSEBT (anterior, posterolateral, posteromedial). The anterior direction had a 135° separation from the posterior directions.[24] The posterolateral and posteromedial direction had a 90° separation between one another.[24] The posterior direction changes depending on the foot that was being tested. Figure 1 shows an example of how the test will be set up.

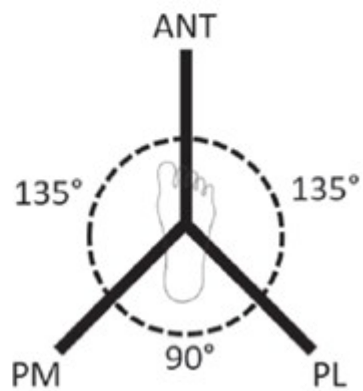

Figure 2. The modified Star Excursion Balance Test for the Right Leg.[24]

Subjects were given specific instructions on how to complete the assessment and what the excluded factors would be before completing the test. Before completing the test, subjects will be given four practice trials of the SEBT for each condition.[13, 20, 24] When reaching towards the anterior direction the toes were placed on the zero line.[5] When reaching towards the posterior directions the heel of the foot was placed on the zero line. Hands were required to stay on the hips throughout the test. If the hands of the subjects were taken off their hips when not holding/wearing the instrument, raise their heel on the stabilizing leg when reaching, lost their balance, rested their reach leg on the ground when reaching, had incorrect foot positioning, and/or were unable to return to the starting position under control then the trial was nullified. The subjects completed three rounds of each reach direction starting with anterior direction, then posteromedial, and concluding with a posterolateral reach. This trial was conducted again, but instead of having their hands on their hips, the subjects held their instrument in their playing position. Each subject was fitted for each instrument and instructed on how to hold each of the instruments. Each instrument was weighed prior to having them fitted to the subjects. Participants performed the SEBT for five different conditions (condition 1 - normal, condition 2 - holding a baritone, condition 3 - holding a tenor saxophone, condition 4 - holding a sousaphone, and condition 5 - holding a tenor drum).

A tape measure was used to measure the reach distances in centimeters. The mean of three rounds were taken, divided by the subject's stance leg length, and multiplied by 100 in order to normalize the reach scores.[55] The following is the formula that was utilized [19, 20, 55]:

$$\frac{Excursion\ Distance}{Leg\ Length} \times 10$$

This was done for all three trials for all conditions. These normalized reach scores were used to calculate the composite score; the average of all three reach scores. The composite score for each condition was calculated using the following formula [55]:

$$[Comp = ((ANT+PM+PL)/(3 \times LL)) \times 100]$$

The values then were compared to the performance of each condition.

Intra-rater reliability was measured for the certified athletic trainer recording the mSEBT, which was assessed by performing the mSEBT on 10 random individuals on two different days. The intra-rater reliability data can be found in Appendix I.

Data Analysis

Summary descriptive statistics for demographic variables were calculated and reported as means and standard deviations for continuous variables while frequencies and percentages were reported for categorical variables. Correlations between variables of body composition were analyzed to better understand the population tested since it is different from previously studied populations in relation to the SEBT. Correlation strengths were categorized as follows in accordance with previously established standards in medical literature: negligible correlation (0.0 to 0.30), low correlation (0.30 to 0.50), moderate correlation (0.50 to 0.70), high correlation (0.70 to 0.90), and very high correlation (0.90 to 1.00) .[56]

Normality was assessed via the Shapiro-Wilk test which revealed the variables of interest were normally distributed. Differences in reach scores between conditions and asymmetries between right and left reach distances in the anterior and composite values were calculated as different values. Asymmetries in anterior and composite scores have been shown to be an indicator of injury risk.[13,22,54] A one-way analysis of variance was used to compare the SEBT reach distances between each condition. A

Bonferroni correction was used during post-hoc analyses with a significance level set a priori at 0.05. Correlations between composite reach scores and variables of body composition were calculated using the Spearman's rho coefficient.

To ensure the consistency of measurement obtained by the examiner, a reliability assessment for each of the 3 SEBT positions was performed. A sample of ten subjects not included in the actual study was obtained for this purpose. Using a two-way random design (2,1), intraclass correlation coefficients (ICC) were calculated from the two trials of each position obtained for a single examiner Intrasession test/retest reliability was calculated. Once the ICC's were determined, standard error of measurement (SEM) and minimal detectable change at the 90% confidence level (MDC90) and 95% level (MDC95) were calculated (Table 1). An ICC greater than 0.75 was interpreted as excellent while values between 0.40–0.75 were considered fair to good and <0.40 was considered poor (Cicchetti 1994).

IV. Results

Thirty-one subjects (n=31) participated in this study. Three (n=3) of these subjects participated solely in the body composition portion of the study, one (n=1) only participated in the SEBT portion of the study, and the remaining twenty-seven (n=27) participated in the entire study. The participant's age (19.67±1.74 years), height (169.72±10.46 cm), weight (81.73±19.96 kg), bone mineral density (1.23±0.12 g/cm^2), total mass (80.75±20.51 kg), fat mass (29.59±12.47 kg), lean mass (48.58±10.50 kg), fat-free mass (51.16±10.95 kg), bone mineral content (2.58±0.49 kg), and relative skeletal muscle mass (7.62±1.46 kg/m^2) were all obtained in the body composition portion of the study.

Correlations between various body composition measures were conducted to understand the population better (Figures 3-8). Scatter plots were used to see the correlations between the various variables of body composition (Figure 3-8). There were very high positive correlations between fat mass and total mass (R^2=0.80/r=0.90) (Figure 3) and between fat-free mass and lean mass (R^2=1/r=1) (Figure 4). There were high positive correlations between fat-free mass and total mass (R^2=0.74/r=0.86) (Figure 5) and between lean mass and total mass (R^2=0.74/r=0.86) (Figure 6). Correlations between fat-free mass and fat mass (R^2=0.29/r=0.54) (Figure 7) and between lean mass and fat mass (R^2=0.30/r=0.55) (Figure 8) were revealed to have moderate positive correlations.

Correlations between reach distance and variables of body composition were analyzed. There was a significant ($p>0.05$), low to moderate negative correlations between total mass and all reach conditions ranging from -0.40 to -0.68 (Table 1). There was a low to moderate negative correlation between fat mass and all reach distances ranging from -0.30 to -0.58, except for condition 1 bilaterally where there was no significant difference (Table 2). Fat-free mass and reach distances were shown to have significant low to moderate negative correlations for conditions 1, 2, and 3 bilaterally and for conditions 4 and 5 for the right leg ranging from -0.32 to -0.60 (Table 3). There was significant low to moderate negative correlations between lean mass and all reach distances, except on the left leg for condition 4 ranging from -0.37 to -0.60 (Table 4). Relative skeletal muscle mass index and reach distances had significant low to moderate negative correlation ranging from -0.35 to -0.58 for all conditions except for the left leg in conditions 1,4, and 5 (Table 5). There was a significant low to moderate negative correlation between bone mineral content and reach distance for conditions 1, 2, and 3, and condition 4 for the right leg ranging from -0.20 to -0.60 (Table 6).

Participants completed the SEBT under five testing conditions: condition 1 - normal, condition 2 - holding a baritone (4 lbs/1.81 kg), condition 3 - holding a tenor saxophone (6 lbs/2.72 kg), condition 4 - holding a sousaphone (27 lbs/ 12.25 kg), and condition 5 - holding a tenor drum (37lbs/16.78 kg without the 5 lbs/ 2.27kg carry). Trials of each reach direction and condition were normalized and reported by stance limb (Table 7). Reach distance generally decreased across conditions with condition 2 being lower than condition 1, condition 3 lower than 2, etc. There were no significant differences between conditions 1-4 ($p \geq 0.05$); however, condition 5 was significantly lower than all other conditions in each reach direction bilaterally ($p \leq 0.05$). There was less than a 1% decrease in composite reach distances for conditions 2 and 3 when compared to the control condition. Composite reach distances decreased by 6% on the left leg and 4% on the right leg when carrying a sousaphone (condition 4) compared to the control trial. Composite reach distances decreased 14% bilaterally when carrying the tenor drums (condition 5).

Asymmetries between limbs were calculated for the anterior and composite reaches (Table 8). The ANOVA did not demonstrate a significant difference across all conditions ($p \geq 0.05$) and therefore post-hoc analyses were not conducted.

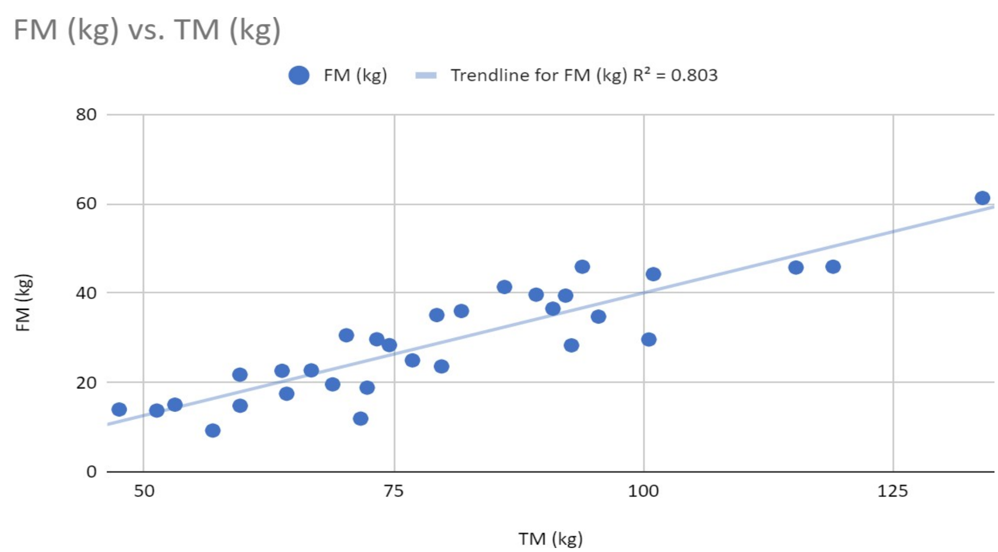

Figure 3. Correlation Between Total Mass and Fat Mass
(Slope= 0.55, Intercept= -14.76)

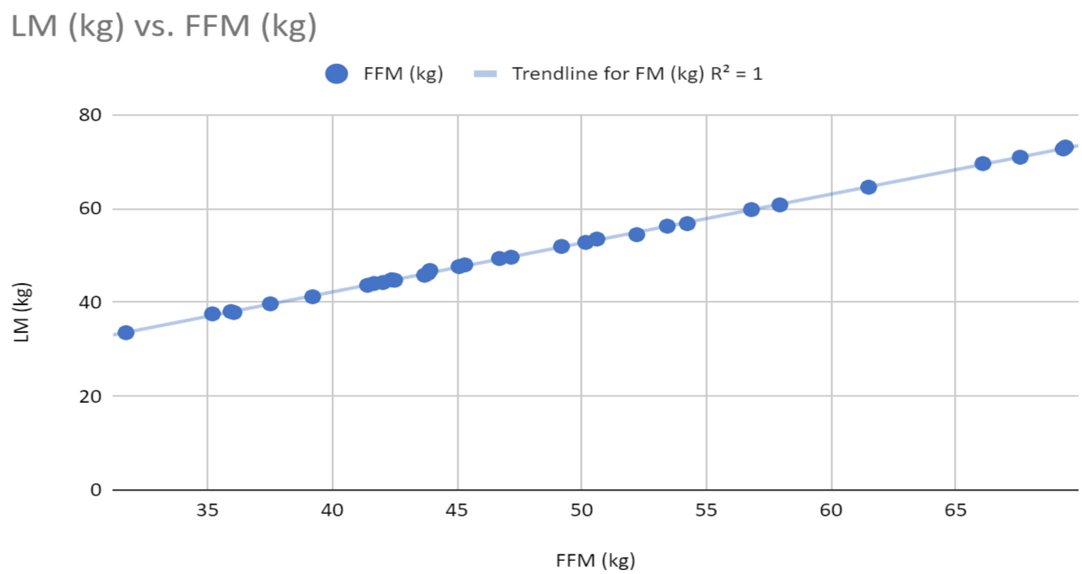

Figure 4. Correlation Between Fat-Free Mass and Lean Mass
(Slope= 0.96, Intercept= -0.49)

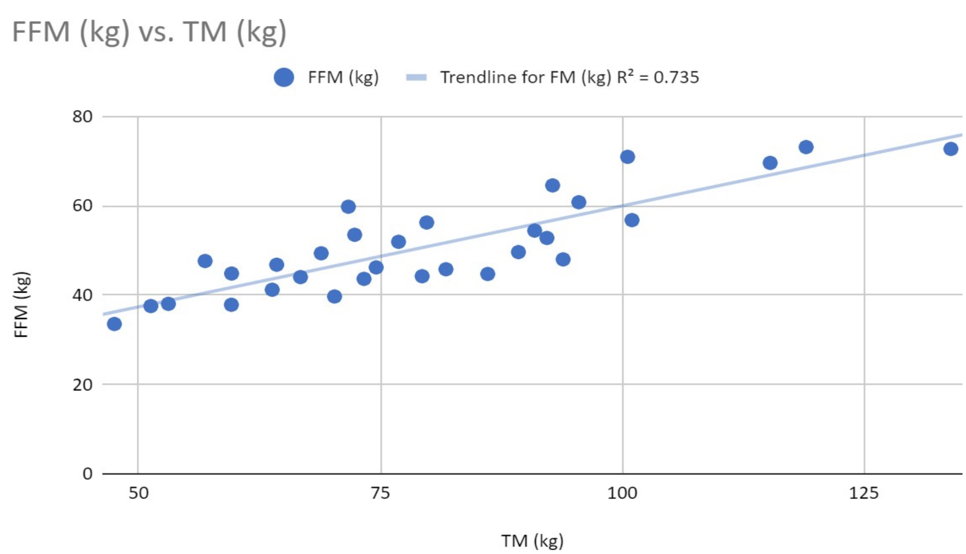

Figure 5. Correlation Between Total Mass and Fat-Free Mass
(Slope= 0.45, Intercept=14.77)

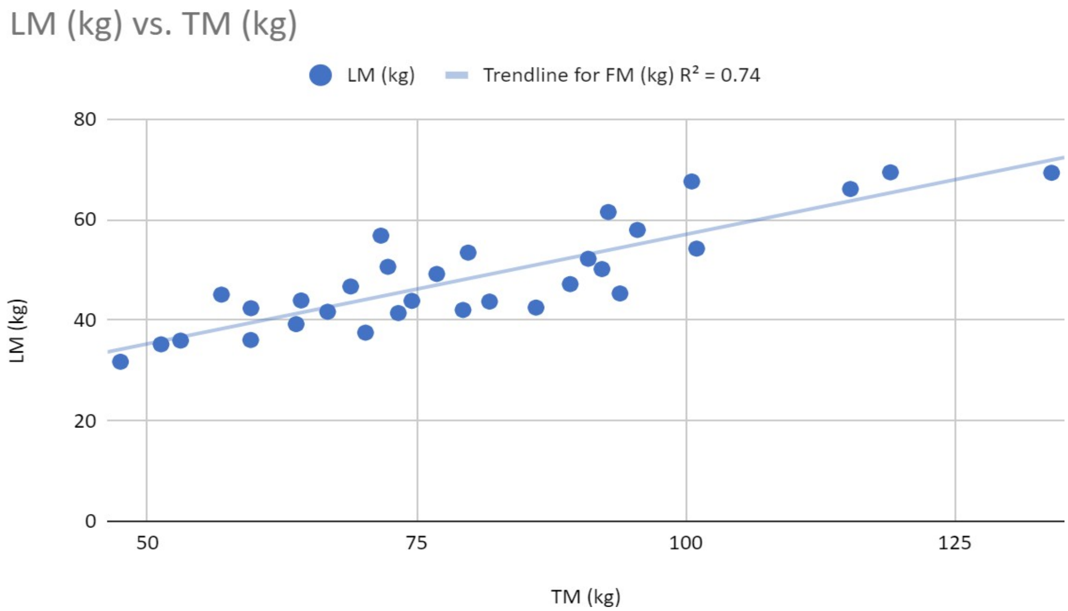

Figure 6. Correlation Between Total Mass and Lean Mass
(Slope= 0.44, Intercept= 13.54)

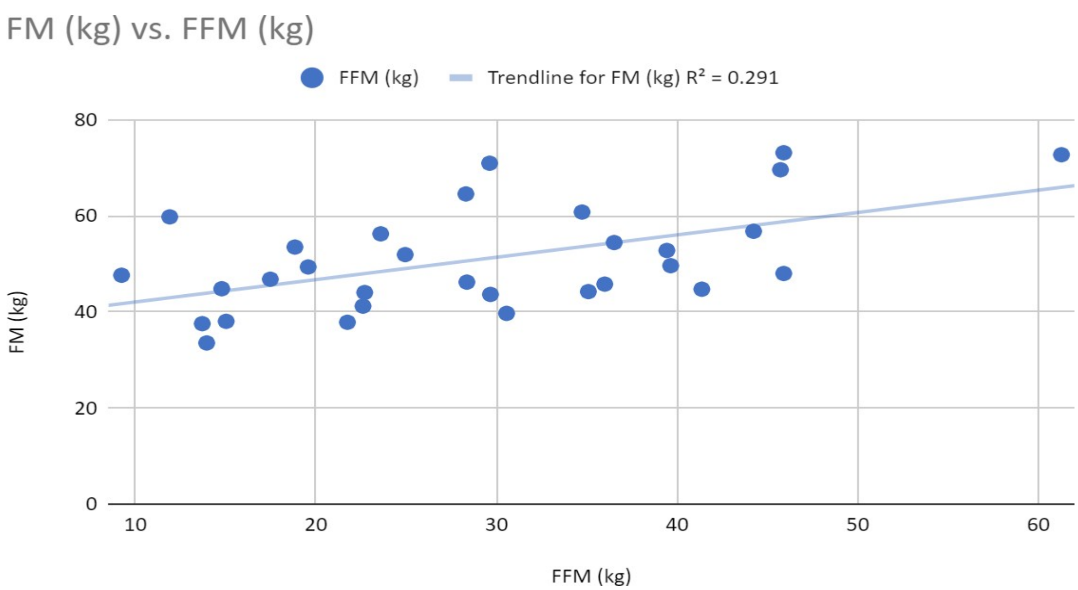

Figure 7. Correlation Between Fat-Free Mass and Fat Mass
(Slope= 0.63, Intercept= -2.79)

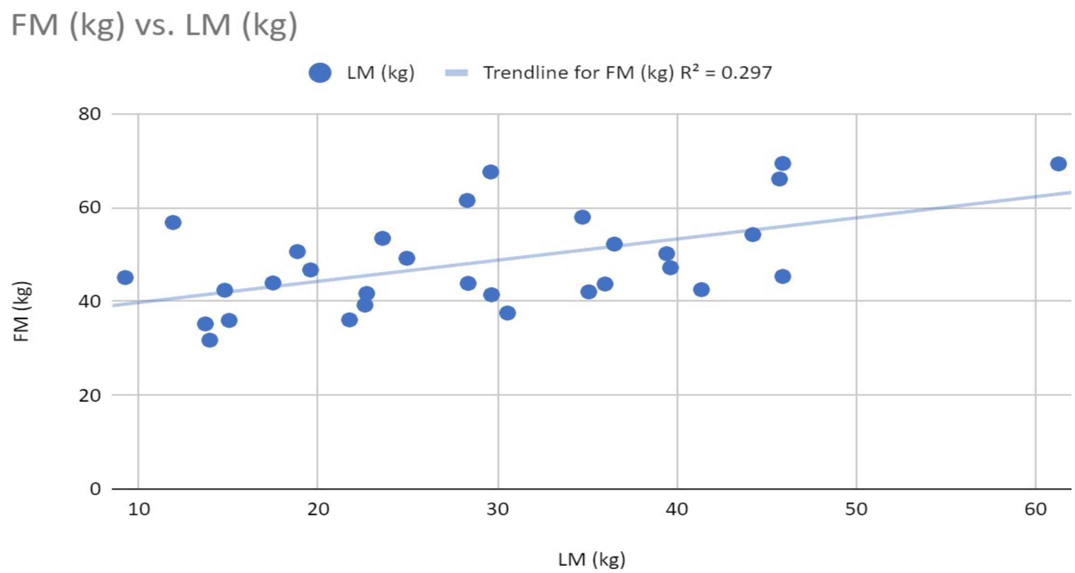

Figure 8. Correlation Between Lean Mass and Fat Mass
(Slope= 0.66, Intercept= -2.78)

Table 1. Total Mass (TM) Correlation with Reach Distances Condition

	Left Leg		**Right Leg**	
Correlations	Spearman's Rho	P-Value	Spearman's Rho	P-Value
Composite Condition 1	-0.4182	0.0299	-0.5073	0.0069
Composite Condition 2	-0.6789	0.0001	-0.6062	0.0008
Composite Condition 3	-0.5330	0.0042	-0.5611	0.0023
Composite Condition 4	-0.4463	0.0196	-0.5244	0.0050
Composite Condition 5	-0.4029	0.0372	-0.4835	0.0106

Table 2. Fat Mass (FM) Correlation with Reach Distances Condition

	Left Leg		Right Leg	
Correlations	Spearman's Rho	P-Value	Spearman's Rho	P-Value
Composite Condition 1	-0.3010	0.1271	-0.3706	0.0570
Composite Condition 2	-0.5849	0.0014	-0.5584	0.0025
Composite Condition 3	-0.4766	0.0120	-0.5257	0.0049
Composite Condition 4	-0.4268	0.0264	-0.4259	0.0268
Composite Condition 5	-0.3819	0.0493	-0.4695	0.0135

Table 3. Fat Free Mass (FFM) Correlation with Reach Distances Condition

	Left Leg		Right Leg	
Correlations	Spearman's Rho	P-Value	Spearman's Rho	P-Value
Composite Condition 1	-0.4438	0.0204	-0.5342	0.0041
Composite Condition 2	-0.6007	0.0009	-0.5037	0.0074
Composite Condition 3	-0.4664	0.0142	-0.4518	0.0180

Composite Condition 4	-0.3797	0.0507	-0.4823	0.0108
Composite Condition 5	-0.3162	0.1080	-0.4054	0.0359

Table 4. Lean Mass (LM) Correlation with Reach Distances Condition

	Left Leg		**Right Leg**	
Correlations	Spearman's Rho	P-Value	Spearman's Rho	P-Value
Composite Condition 1	-0.4389	0.0220	-0.5305	0.0044
Composite Condition 2	-0.5989	0.0010	-0.5000	0.0079
Composite Condition 3	-0.4628	0.0151	-0.4481	0.0191
Composite Condition 4	-0.3748	0.0540	-0.4817	0.0110
Composite Condition 5	-0.3999	0.0388	-0.5279	0.0046

Table 5. Relative Skeletal Mass Index Correlation (RSMI) with Reach Distances Condition

	Left Leg	**Right Leg**

Correlations	Spearman's Rho	P-Value	Spearman's Rho	P-Value
Composite Condition 1	-0.3486	0.0747	-0.4931	0.0090
Composite Condition 2	-0.5807	0.0015	-0.4833	0.0107
Composite Condition 3	-0.4158	0.0310	-0.4067	0.0353
Composite Condition 4	-0.3551	0.0692	-0.4662	0.0142
Composite Condition 5	-0.3700	0.0575	-0.4821	0.0109

Table 6. Bone Mineral Content (BMC) Correlation with Reach Distances Condition

	Left Leg		**Right Leg**	
Correlations	Spearman's Rho	P-Value	Spearman's Rho	P-Value
Composite Condition 1	-0.5279	0.0046	-0.6034	0.0009
Composite Condition 2	-0.5362	0.0039	-0.4785	0.0116
Composite Condition 3	-0.4947	0.0087	-0.4721	0.0129
Composite Condition 4	-0.3460	0.0771	-0.4153	0.0312
Composite Condition 5	-0.1969	0.3248	-0.2614	0.1879

Table 7. Normalized SEBT Values by Condition

Left	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5
ANT	67.99±5.40*	66.33±5.48*	65.83±5.66*	64.67±5.73*	56.67±6.46
PM	80.56±7.40*	79.85±7.54*	80.39±9.40*	74.69±7.89*	72.92±8.28
PL	71.66±7.15*	71.83±10.00*	71.62±10.62*	68.91±10.99*	60.28±13.20
Composite	81.91±7.92*	81.10±10.19*	81.03±10.19*	77.35±8.85*	70.29±9.08
Right					
ANT	69.53±5.09*	67.02±5.81*	66.90±5.10*	65.95±4.94*	57.31±5.88
PM	79.47±8.32*	80.16±8.28*	79.43±9.75*	76.75±8.24*	70.61±7.51
PL	72.48±7.68*	74.94±9.98*	73.86±11.23*	69.47±11.05*	62.20±13.82
Composite	82.35±8.64*	82.48±8.94*	81.81±9.83*	78.89±8.44*	70.54±9.28

*Significantly less compared to condition 5 (p≤0.05)

Table 8. Bilateral differences in Normalized Anterior and Composite Reach Distances

	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5	P-value
Anterior	3.29±2.12	2.16±2.00	2.80±2.54	2.69±1.86	3.03±1.65	0.33

Composite	2.40±2.08	2.06±1.60	2.10±1.98	2.92±2.36	2.44±1.71	0.49

V. Discussion

From the initial analysis of body composition variable, it is clear that this population may differ greatly from athletic populations that have been used to set the predictive values of the SEBT. All factors of body composition decreased reach distances, where total mass had the most amount of significant correlations. It was suspected that total weight and fat mass would be correlated in decreasing reach distances, while fat-free mass, lean mass, and the relative skeletal mass index would aid in improving or not significantly affecting reach scores, but the results showed otherwise. All factors of body composition showed to be correlated in decreasing reach scores. This can be due to the fact that weighing more makes it more difficult to be proficient in dynamic stability. Having a higher amount of muscle mass was thought to help improve performance on the SEBT because greater muscle mass allows for greater force production (i.e., greater strength) to help keep individuals stabilized when reaching. Although the results show otherwise this still may be true. Many of the participants of this study had high levels of fat mass (FM%= 35.17±8.674). The amount of lean mass that the subjects had could have been insufficient enough to overcome the adverse factors contributed by fat mass. Additionally, when having such high levels of fat mass, lean mass can increase as well. Lean mass takes body composition variables such as bone mass, organ mass, and muscle mass into account except for non-essential fat. It can be assumed that lean mass could have had a high positive correlation with total mass because of the increase in skin mass (to sustain all of the excess adipose tissue), and muscle and bone mass (both needed to help carry their weight). Future investigations should aim to look at how segmental body composition variables affect performance on the SEBT. For instance, how would having higher amounts of adipose tissue in the trunk or upper extremity differ from individuals with higher amounts of adipose tissues in the lower extremity when looking at performance on the SEBT.

The results of this study revealed that performance on the SEBT was significantly diminished when wearing the tenor drums compared to all other conditions for all reach directions. The application of the tenor drums decreased composite reach distances by 14%. This condition was unique from all other conditions because the load was displaced anteriorly. A possibility as to why reach scores were significantly different can be due to it being the heaviest carriage and where the load was localized. The tenor drums, without the additional 5lbs/2.27 kg from the carry, weighed approximately 37lbs/16.82 kg which was 12-30% of the participant's body weight. To help keep them stabilized the subjects were required to engage their core and low back muscles. Considering that many of the subjects that participated in this study did not play the tenor drum as their main instrument they could have been unfamiliar with how to stay stabilized while carrying this instrument. Furthermore, many of these individuals could have had weak core stabilizing muscles or lacked the neuromuscular engagement of these muscles which may have contributed to their instability and made them unable to reach as far as when wearing the instrument. Although it was accounted for and adjusted for, another factor that could have contributed to this was the placement of the tenor drum. If the tenor drum was placed too low, it could have disrupted the stance leg when reaching, not allowing for full reach distance. This possibility is unlikely, however, because the instrument was adjusted to each subject to prevent disruption when reaching.

Performing the SEBT with tenor drums significantly decreased reach scores. Although the injury rate was not monitored, this could potentially mean that these tenor drum players may be at greater risk of lower extremity injury than the other marching band performers. Future research should specifically look at these performers and see the prevalence of lower back and lower extremity injury in relation to performance in the SEBT. If these types of injuries are prevalent in this population, then perhaps the SEBT has the potential to let clinicians know which tenor drum performer may be at risk.

Contrary to Denehey's study, reach scores did not seem to be significantly affected when the external load was placed axially.[6] Denehey et al. had Division III football players perform the SEBT while having on their football equipment which weighed 6.2 kg, while this study had the participants carry a sousaphone which weighed about 12.3kg. Their results revealed that there was a significant difference in reach scores for the posterolateral reaches, anterior reach on the right leg, and right leg composite scores. The average body fat percentage for the subjects in Denehey et al.'s study was 20.90±7.360 whereas the mean body fat percentage for the participants in this study was 35.17±8.674. Logically, one would assume that having an additional

6.1kg along with having an extra 14% in body fat would cause more significant differences in reach scores, but the results showed otherwise. This can be due to testing order and level of training from the start of the study. In this study, the subjects were required to perform 4 practice trials prior to every condition in the same testing order. The testing order was as follows: non-weighted, baritone, tenor saxophone, sousaphone, and tenor drums. This would mean that the subject had 25 trials to go through the movements of the SEBT prior to the recorded sousaphone trial. When comparing how the subjects performed on the SEBT when non-weighted to how the subjects in Denehey's study performed, the marching band participants performed significantly poorer than the Division III football players in all reach distances and composite scores. Although external load increased, there was no significant change in performance, which could have been attributed to the marching band subjects becoming more "trained" as they continued to perform the SEBT. There was no significant improvement in reach scores as well. Since there was no significant difference in reach distance when being vertically loaded, it can be surmised that the participants had become more trained in performing the SEBT, but the improvement in skill level was negated by the external load.

Although the reasoning as to why there was no significant difference when this study had higher internal and external loads is speculative, future research should aim in observing performance on the SEBT in this population while wearing a sousaphone without having the subject have too many trials where skill level will improve and thus skew results. This investigation can help clinicians know if wearing a sousaphone truly does not significantly impede performance on the SEBT.

Asymmetrical differences in anterior reaches and composite scores have been linked to an increased risk of lower extremity injury.[22, 54] It was predicted that having an additional external load when performing the SEBT would be capable of revealing asymmetrical reach differences that would not be shown when not wearing an instrument. However, external load from an instrument did not magnify asymmetrical reach differences that are not shown with no carriage. From these findings, it can be assumed that external loads have no significance in revealing asymmetries that may not have been present when not loaded, thus testing under normal conditions is sufficient.

The subjects of this normalized composite reach scores were 81.91±7.92% of limb length for left leg reaches and 82.35±8.64% of limb length for right leg reaches. According to Plisky et al. the majority of the subjects that participated in this study are 6.5 times more likely to sustain a lower extremity injury in all conditions because their composite reach scores were below 94% of their leg length.[22] The same can be said based on Butler et al.'s study. Occurring to Butler et al. these performers are 3.5 times more likely to get injured because they have reached cores below 89.6% of the stance limb. However, Plisky et al.'s study investigated high school basketball athletes, and Butler et al.'s observed, collegiate football players. In these sports, the athletes need to engage in movements such as running, jumping, landing, or cutting which is something that marching band performers usually do not need to partake in. Furthermore, these are contact sports, so the impact from these sports can contribute to the prevalence of injury which is not seen when marching. Even though these athletes engage in similar activities to one another there is still about a 4% difference in reach scores that reveal various levels of injury risk. Based on the differences found in Plisky et al.'s, Butler et al.'s, and this study, normative values of the SEBT are population specific. If clinicians want to use the SEBT as a pre-screening tool, the clinician must investigate and see what the normative values for their specific population are to get a true idea of what the cut-off reach distance point is and what the probability of injury for individuals who fall under the cut-off point will be. Considering the lack of research, future studies should investigate what normalized composite reach distances would make these performers more susceptible to sustaining lower extremity injuries.

From the data gathered from this investigation, conducting the SEBT under normal conditions is sufficient enough to test for functionality, except if you are a performer who marches with the tenor drums. Since this condition had significantly lower reach scores compared to all other conditions, it is suspected that testing these performers on SEBT while having their instrument on may be necessary; however, the connection to injury still needs to be investigated.

Limitations

There were various limitations in this study. There was a small sample size (n=27), and the subject population was not specific to their actual condition.

Additionally, the conditions of this study were not randomized. It was thought to help limit the amount of type I errors, the load placed on the subjects should have been gradually increased in order to help with fatigue or to allow the subjects to get accustomed to performing the SEBT with the external loads from the instrument (many of whom were not experienced wearing or holding the instrument. However, doing this could have increased type II errors because of the increase in trainability the subjects go through as the more and more they perform the SEBT. Another limitation was the subject's familiarization with wearing the instrument they were tested on. A flutist who has never played and worn the tenor drums will be disadvantaged against a seasoned tenor drum player being tested with the same instrument. As previously mentioned, fitting, the tenor drums could have affected the results. If the drums rested too low, it would not allow for full reach because the drums could have collided with the drums not allowing for the subjects to go through their maximal excursion distance. If rested too it would not truly mimic functionality and could have moved the subject's center of gravity up making them more unstable than they would be in their activity.

Field of vision could have been a limiting factor. The tenor drums made reaching anteriorly difficult because it was blocking where the tape was. The same issue occurred when carrying the sousaphone because it made it difficult for subjects to see the posteromedial and posterolateral reach differences. However, even with vision being disrupted, when holding a sousaphone reach distances in any direction did not reveal a statistically significant decrease in normalized reach scores. Similarly, reach distances were significantly lower in all conditions regardless of if the subjects were able to see the tape. Lastly, when performing, marching band performers are not looking at where they are going. They tend to be in a fixed position moving in various directions. Knowing this, the disruption of their field of vision may have had a minimal effect on performance.

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APPENDICES

Appendix A: Invitation to Study Script

Verbal script:

Hello_______! Are you interested in being a part of my thesis study? I will be conducting a study on the marching band this semester and I need volunteers to go through different tests. The purpose of the study is to find out how a test used to measure your balance and leg motion (known as the Star Excursion Balance Test (SEBT)) can be affected when holding added weight from specific instruments (baritone, sousaphone, tenor drums, and tenor saxophone) in marching band performers. The SEBT is a test for your legs that allows us to know if you may be at risk of leg injuries. All you have to do is balance on one leg and reach in 3 different directions as far as you can without losing your balance. You will have four practice trials and three assessment trials. Once you complete it you will then repeat the steps four different times, but in each of the trials you will be holding a different instrument. The instruments are baritone, tenor saxophone, sousaphone, and tenor drums.

I will also be looking at body composition and how it relates to leg injuries that happen during your season. As a subject in the study, you will be asked to stand on two different kinds of scales to measure body composition and then be scanned by a DEXA machine. For the DEXA, all you have to do is lay on a table until the machine is done scanning (this takes about 10 minutes). Once you have completed all of the tests, you will be free to go.

> Yes: I will contact you with a sign-up sheet to come into the lab and get scanned so keep an eye on your email.
>
> No: Thank you for your time and consideration.

Email sample:

> Marching Colonels,

I am reaching out to you with an opportunity to help me with my master's thesis. The study is called The Effects of External Load and Body Composition on the SEBT in Marching Band Performers. I will be conducting a study on Eastern Kentucky's marching band (you!), and I need volunteers to go through different tests. The purpose of the study is to find out how a test used to measure your balance and leg motion (known as the Star Excursion Balance Test (SEBT)) can be affected when holding added weight from specific instruments (baritone, sousaphone, tenor drums, and tenor saxophone) in marching band performers. The SEBT is a test for your legs that allows us to know if you may be at risk of leg injuries. All you have to do is balance on one leg and reach in 3 different directions as far as you can without losing your balance. You will have four practice trials and three assessment trials. Once you complete it you will then repeat the steps four different times, but in each of the trials you will be holding a different instrument. The instruments are baritone, tenor saxophone, sousaphone, and tenor drums. I have attached a link so you could get an idea of what this test looks like, the only difference is that you will be reaching in three different directions not eight as shown in the video. https://www.youtube.com/watch?v=GBT9V78d6E0.

I will also be looking at body composition and how it relates to lower extremity injuries that happen during your season. As a subject in my study, you will be asked to stand on two different kinds of scales to measure body composition and then be scanned by a DEXA machine; all you have to do for the DEXA is lay on the table until the machine is done scanning. As a subject you will not be paid, but I would appreciate if I could get as many volunteers scanned as possible.

I am looking for anyone that is interested, so don't be shy and please reach out if you would like to be a subject in my study. If you have any questions about the study or have an interest in being a subject, please contact me via email (alexander_alvarez10@mymail.eku.edu) or come in to see me in the clinic.

If you have already gotten in touch with me, I will be contacting you soon with times and dates available for you to come into the lab.

Thank you,

Alexander Alvarez, LAT, ATC Graduate Assistant Athletic Trainer Eastern Kentucky University

Appendix B: Informed Consent Form

Consent to Participate in a Research Study

The Effects of External Load and Body Composition on the SEBT in Marching Band Performers

Key Information

You are being invited to participate in a research study. This document includes important information you should know about the study. Before providing your consent to participate, please read this entire document and ask any questions you have.

Do I have to participate?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you chose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. You cannot take part in this study if you are pregnant or could be pregnant. If you decide to participate, you will be one of about 150 people in the study.

What is the purpose of thestudy?

The purpose of the study is to find out how a test used to measure your balance and leg motion (known as the Star Excursion Balance Test (SEBT)) can be affected when holding added weight from specific instruments (baritone, sousaphone, tenor drums, and tenor saxophone) in marching band performers. The second purpose of this study will see if the SEBT can predict if injuries will occur to your legs over time. The third purpose of this study is to see if body composition can predict injury patterns in collegiate marching band performers.

Where is the study going to take place and how long will it last?

The research procedures will be conducted at Eastern Kentucky University's campus. You will need to come to Moberly 223 for the body composition portion of the study. This visit will take about 1 hour. For the SEBT portion of the study, you will need to the Moberly or Foster building. The location of the room will be based on room availability. This visit will take about 1 hour.

What will I be asked to do?

After signing the necessary documents, you will complete 2 questionnaires asking you how well you can use your ankles, feet, and legs during certain tasks (i.e., walking, running, etc). Then you will have your height, blood pressure, and heart rate measured. After that, we will ask you to step onto a scale and input some basic information about yourself. The scale will then print a piece of paper with information about your body weight and body make-up. After the paper prints, we will ask you to step onto a different platform and place your hands on a separate device where indicated. This device will measure body composition using low level electrical current. You will not feel the current as it passes through you. The device will also require some basic background information (i.e., height, weight, sex, birthday, etc.) to be entered. After you step off the device, we will then determine your body composition using what is known as a DEXA scanner. The DEXA is a machine that uses low-level X-rays to measure how much of your body is made up of bones, fat, and muscle. However, if you weigh 350 pounds or more, the DEXA scanner cannot be utilized. If this occurs, testing will stop after the scale and only the body weight and body composition from the first 2 devices will be used for the study. Finally, data from the DEXA will be compared with any injury you reported during the fall 2021 marching band season. If you participated in the marching band during the 2020 season, the electronic medical record (EMR) notes maintained by the athletic trainer assigned to cover the band will be accessed in order to identify any general medical, environmental, or musculoskeletal injury that may have occurred related to marching band during 2020. If you are a returning marching band participant or a new marching band participant, the same EMR records will be reviewed for any injury that may occur throughout the 2021 season.

After measuring your body composition, we will measure how long your legs are. After that, you will complete the star excursion balance test (SEBT). The SEBT requires you to stand on one foot and reach as far as you can in three different directions with the other foot. You will complete this with both legs and will be given 4 practice trials. After the practice trials, you will reach towards each direction three times. Once you complete this, you will then complete it four different times holding a different instrument each time. The instruments will be baritone, sousaphone, tenor drums, and tenor saxophone. The tenor drums and tenor saxophone will be fitted to you. In all, this should take 1 hour to complete. The data we collect from your reach distances and leg length will be entered into a formula and will give a score which will be analyzed for this study.

Are there reasons why I should not take part in this study?

You will be excluded from this study if you are pregnant or may be pregnant, are under the age of 18, not a participant in the EKU Marching Colonels (MCs) or refuse to sign the DXA waiver and/or consent form.

What are the possible risks and discomforts?

To the best of our knowledge, the assessments you will be doing have no more risk of harm or discomfort than you would experience in everyday life. There are little to no risks with the body composition testing using the scale or handheld device. For both the scale and bioelectrical impedance body composition devices, the electrical currents created are too small to be felt. The DEXA carries certain inherent risks and dangers. These risks, as with any device, could include, but are not limited to personal damage, injury, paralysis, loss, death, or property damage or loss. With the results being so personal, the research team will only make the results available to you and no one else. Although we have made every effort to minimize this, you may find some questions we ask you (or some procedures we ask you to do) to be upsetting or stressful. If so, we can tell you about some people who may be able to help you with these feelings (i.e., EKU Counseling Center for EKU students). Finally, you may experience muscle soreness after the SEBT. The muscle soreness will likely be no greater than soreness felt after 1-2 hours of marching or after a strenuous exercise routine.

You may, however, experience a previously unknown risk or side effect.

What are the benefits of taking part in this study?

You are not likely to get any personal benefit from taking part in this study. Your participation is expected to provide benefits to others by giving the researchers data that may help identify those at risk of leg injury or those with less-than-ideal balance.

If I don't take part in this study, are there other choices?

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

Now that you have some key information about the study, please continue reading if you are interested in participating. Other important details about the study are provided below.

Other Important Details

Who is doing the study?

The person in charge of this study is Alexander Alvarez at Eastern Kentucky University. He is being guided in this research by Dr. Aaron Sciascia. There may be other people on the research team assisting at different times during the study.

What will it cost me to participate?

There are no costs associated with taking part in this study.

Will I receive any payment or rewards for taking part in the study?

You will not receive any payment or reward for taking part in this study.

Who will see the information I give?

Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about this combined information. You will not be identified in these written materials.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from the information you give, and these two things will be stored in different places under lock and key.

However, there are some circumstances in which we may have to show your information to other people. For example, the law may require us to show your information to a court. Also, we may be required to show information that identifies you for audit purposes.

Can my taking part in the study end early?

If you decide to take part in the study, you still have the right to decide at any time that you no longer want to participate. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to end your participation in the study. They may do this if you are not able to follow the directions they give you, if they find that your being in the study is more risk than benefit to you, or if the University or agency funding the study decides to stop the study early for a variety of reasons.

What happens if I get hurt or sick during the study?

If you believe you are hurt or get sick because of something that is done during the study, you should call Alexander Alvarez at (786) 312-6190 or Aaron Sciascia (859) 622-3495immediately. It is important for you to understand that Eastern Kentucky University will not pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. Also, Eastern Kentucky University will not pay for any wages you may lose if you are harmed by this study. These costs will be your responsibility.

Usually, medical costs that result from research-related harm cannot be included as regular medical costs. Therefore, the costs related to your care and treatment because of something that is done during the study will be your responsibility. You should ask your insurer if you have any questions about your insurer's willingness to pay under these circumstances.

What else do I need to know?

You will be told if any new information is learned which may affect your condition or influence your willingness to continue taking part in this study.

We will give you a copy of this consent form to take with you.

Consent

Before you decide whether to accept this invitation to take part in the study, please ask any questions that come to mind now. Later, if you have questions about the study, you can contact the investigator, Alexander Alvarez at alexander_alvarez10@mymail.eku.edu. If you have any questions about your rights as a research volunteer, you can contact the staff in the Division of Sponsored Programs at Eastern Kentucky University at 859-622-3636.

If you would like to participate, please read the statement below, sign, and print your name.

I am at least 18 years of age, have thoroughly read this document, understand its contents, have been given an opportunity to have my questions answered, and voluntarily agree to participate in this research study.

Signature of person agreeing to take part in the study Date

Printed name of person taking part in the study

Name of person providing information to subject

Appendix C: DEXA Waiver

Eastern Kentucky University

Waiver of Liability, Assumption of Risk, and Indemnity Agreement

THIS IS A LEGALLY BINDING RELEASE, WAIVER, INDEMNIFICATION OF LIABILITY, AND EXPRESS ASSUMPTION OF RISK.
Please read it carefully, fill in all blanks and **initial each paragraph** before signing.

__________________I,_____, hereby affirm that I have read this document in its entirety. By my signature below and by my **initialing each paragraph**, I agree to each and every term and condition of this document.

__I UNDERSTAND THAT PARTICIPATION IN **The Effects of External Load and Body Composition on the SEBT in Marching Band Performers** (hereafter referred to as "Event"), which involves body composition evaluation, CARRIES WITH IT CERTAIN INHERENT RISKS AND DANGERS. THESE RISKS INCLUDE, BUT ARE NOT LIMITED TO: PERSONAL DAMAGE, INJURY, PARALYSIS, LOSS, DEATH, OR PROPERTY
DAMAGE OR LOSS. I understand that these risks are described by way of example only, and that there are numerous other risks inherent in this activity to which I may be exposed. In the event of possible injury, I give permission for EKU to authorize the administration of medical care.

____IN CONSIDERATION OF BEING PERMITTED TO PARTICIPATE IN ANY WAY IN__________at___________, on I, on behalf of my myself and anyone claiming interest through me, DO HEREBY INTENTIONALLY, KNOWINGLY, AND VOLUNTARILY RELEASE, WAIVE, DISCHARGE, INDEMNIFY, AND AGREE TO HOLD HARMLESS EASTERN KENTUCKY UNIVERSITY, and
all its employees, regents, volunteers, and representatives FROM ANY AND ALL CLAIMS, ACTIONS, SUITS, PROCEDURES, COSTS, EXPENSES, DAMAGES, AND LIABILITIES brought as a result of my involvement in this event, whether such damage, injury, or loss results from NEGLIGENCE or some other cause, and to reimburse them for any such expenses incurred.

__I understand that the University in no way represents, or acts as an agent for, any third-party trip organizer, the transportation carriers, hotels, and other suppliers of service during this event. I understand and agree that the University is not responsible for losses or expenses due to sickness, weather, strikes, hostilities, wars, natural disasters, or other such causes or disruptions. Further, the University is not responsible for any disruption of travel arrangements, or any consequent additional expenses that may be incurred therefrom.

__I am not pregnant and have been informed of the risk and potential consequences of participating in this program while pregnant.

__I HEREBY ASSERT THAT MY PARTICIPATION IS VOLUNTARY AND THAT I KNOWINGLY ASSUME ALL SUCH RISKS. I acknowledge that
EKU has not required, coerced, or encouraged me to participate in this event. I understand that I signed this document as my own free act and deed; no oral representations, statements, or inducements, apart from the foregoing written statement, have been made.

*Phone Number:________________________*E-mail Address: _____________________________

*Phone Number:_______________________________*E-mail Address: ______________________

Sign name Print name Date

____

Signature of Parent or Guardian (if under 18 years of age):

____

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Appendix D: The Foot and Ankle Disability Index (FADI) Score and Sports Module

The Foot and Ankle Disability Index (FADI) Score and Sports Module

Patient Name:____Date: ___________

Please answer every question with one response that most closely describes your condition within the past week by marking the appropriate number in the box. If the activity in question is limited by something other than your foot or ankle, mark N/A.

0 Unable to do 2 Moderate difficulty 4 No difficulty 1 Extreme difficulty 3 Slight difficulty

Standing	
Walking on even ground	
Walking on even ground without shoes	
Walking on uneven ground	
Stepping up and down curves	
Sleeping	
Walking initially	
Walking approximately 10 minutes	
Home responsibilities	
Personal Care	
Heavy work (push/pulling, climbing, carrying)	

Sports Module:

Running	
Landing	
Cutting, lateral movements	
Ability to perform activity with your normal technique	

Pain related to the foot and ankle:

Walking up hills	
Walking down hills	
Going up stairs	
Going downstairs	
Squatting	
Coming up to your toes	
Walking 5 minutes or less	
Walking 15 minutes or greater	
Activities of Daily Living	
Light to moderate work (standing, walking)	
Recreational activities	

Jumping	
Squatting and stopping quickly	
Low-impact activities	
Ability to participate in your desired sports as long as you would like	

0 Unbearable 2 Moderate Pain 4 No Pain 1 Severe Pain 3 Mild Pain

General level of pain	
Pain during your normal activity	

Pain at rest	
Pain first thing in the morning	

Score: ____/136 points (FADI 104 points & SPORTS 32 points; No Disability 136) Number of PT Sessions: _____ Gender: M F Age:_____ ICD-9 Code: PT Initials:

Appendix E: Lower Extremity Functional Scale (LEFS)

Lower Extremity Functional Scale (LEFS)

Source: Binkley JM, Stratford PW, Lott SA, Riddle DL. The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. North American Orthopaedic Rehabilitation Research Network. *Phys Ther*. 1999 Apr;79(4):371-83.

The Lower Extremity Functional Scale (LEFS) is a questionnaire containing 20 questions about a person's ability to perform everyday tasks. The LEFS can be used by clinicians as a measure of patients' initial function, ongoing progress and outcome, as well as to set functional goals.

The LEFS can be used to evaluate the functional impairment of a patient with a disorder of one or both lower extremities. It can be used to monitor the patient over time and to evaluate the effectiveness of an intervention.

Scoring instructions

The columns on the scale are summed to get a total score. The maximum score is 80.

Interpretation of scores

③the lower the score the greater the disability.

③the minimal detectable change is 9 scale points.

③the minimal clinically important difference is 9 scale points.

③% of maximal function = (LEFS score) / 80 * 100

Performance:

③the potential error at a given point in time was +/- 5.3 scale points.

③Test-retest reliability was 0.94.

③Construct reliability was determined by comparison with the SF-36. The scale was found to be reliable with a sensitivity to change superior to the SF-36.

Instructions

We are interested in knowing whether you are having any difficulty at all with the activities listed below **because of your lower limb problem** for which you are currently seeking attention. Please provide an answer for **each** activity.

Today, *do you* or *would you* have any difficulty at all with:

Activities	Extreme difficulty or unable to perform activity	Quite a bit of difficulty	Moderate difficulty	A little bit of difficulty	No difficulty
1. Any of your usual work, housework or school activities.	0	1	2	3	4
2. Your usual hobbies, recreational or sporting activities.	0	1	2	3	4
3. Getting into or out of the bath.	0	1	2	3	4
4. Walking between rooms.	0	1	2	3	4
5. Putting on your shoes or socks.	0	1	2	3	4
6. Squatting.	0	1	2	3	4
7. Lifting an object, like a bag of groceries from the floor.	0	1	2	3	4
8. Performing light activities around your home.	0	1	2	3	4
9. Performing heavy activities around your home.	0	1	2	3	4
10. Getting into or out of a car.	0	1	2	3	4
11. Walking 2 blocks.	0	1	2	3	4
12. Walking a mile.	0	1	2	3	4
13. Going up or down 10 stairs (about 1 flight of stairs).	0	1	2	3	4
14. Standing for 1 hour.	0	1	2	3	4
15. Sitting for 1 hour.	0	1	2	3	4
16. Running on even ground.	0	1	2	3	4
17. Running on uneven ground.	0	1	2	3	4
18. Making sharp turns while running fast.	0	1	2	3	4
19. Hopping.	0	1	2	3	4
20. Rolling over in bed.	0	1	2	3	4
Column Totals:	0	1	2	3	4

Appendix F: Reliability Assessment

No Instrument	Ant. R	Ant. L	PM R	PM L	PL R	PL L
ICC	0.93	0.82	0.98	0.96	0.97	0.95
95% CI Lower	0.72	0.26	0.9	0.86	0.89	0.81
95% CI Upper	0.98	0.95	0.99	0.99	0.99	0.99
Mean	63.93	66	78	80	69	73
SD	6.93	7	13	15	16	13
SEM	1.83	2.95	1.88	3.01	2.73	3.01
MDC90	4.28	6.88	4.38	7.02	6.37	7.03
MDC95	5.08	8.17	5.20	8.34	7.57	8.35
Sousaphone						
ICC	0.96	0.89	0.97	0.96	0.94	0.97
95% CI Lower	0.84	0.58	0.89	0.84	0.75	0.88

95% CI Upper	0.99	0.97	0.99	0.99	0.98	0.99
Mean	62	63	76	79	68	71
SD	6	6	15	14	18	13
SEM	1.28	2.02	2.52	2.85	4.31	2.20
MDC90	2.98	4.71	5.89	6.66	10.06	5.14
MDC95	3.54	5.59	7.00	7.91	11.95	6.10

Ant. R= Anterior reach with right leg; Ant. L= Anterior reach with left leg; PM R= Posteromedial reach with right leg; PM L = Posteromedial reach with left leg; ICC=intraclass correlation coefficient; PL R= Posterolateral reach with right leg; PL L= Posterolateral reach with left leg ;95%CI=95% confidence interval; SD=standard deviation; SEM=standard error of measurement; MDC=minimal detectable change