# THE EFFECTS OF LOWER EXTREMITY FATIGUE ON POSTURAL CONTROL WITH PERTURBATIONS OVER TIME IN PHYSICALLY ACTIVE MALES AND FEMALES

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## ABSTRACT


THE EFFECTS OF LOWER EXTREMITY FATIGUE ON POSTURAL CONTROL WITH PERTURBATIONS OVER TIME IN PHYSICALLY ACTIVE MALES AND FEMALES

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**Context:** Research has shown that fatigue adversely effects postural control but little research has been done using the sophistication of computerized dynamic posturography. **Objective:** The purpose of this study was to determine the effects of lower extremity fatigue on postural control with ankle, knee, and hip perturbations. **Design:** A pre-test post-test design. **Setting:** Controlled research laboratory. **Participants:** Thirty physically active males and females (age=22±2.54 yrs, height=166.77±8.59cm, weight = 65.51± 3.01kg) volunteered to participate in this investigation. **Intervention:** Subjects performed the Motor Control Test (MCT) before and after 4 episodes of fatigue. Bilateral body weight squats were repeated until the point of fatigue, when the participants could no longer complete three consecutive squats. repeated measures ANOVA and paired t-test for pre and post fatigue composite latency scores. **Main outcome Measure:** Latency scores produced by the (MCT) were recorded before and after fatigue. **Results:** No differences in fatigue were observed across trials following fatigue trials $F(4,112)=1.3$, $p=.264$. A gender effect was observed $F(1,28) = 12.3$, $p = .002$, was observed across all trials. Males had higher (worse) latency levels than females. **Conclusion:** There were no differences found between pre fatigue and post fatigue trials contrary to the hypothesis in this investigation. The mean latency scores did not illustrate that muscular fatigue has an effect on postural balance or control.

# CHAPTER I

# THE EFFECTS OF LOWER EXTREMITY FATIGUE ON POSTURAL CONTROL WITH PERTURBATIONS OVER TIME IN PHYSICALLY ACTIVE MALES AND FEMALES

## Introduction

Lower extremity fatigue is a natural phenomenon that occurs in sports participation. Poor postural control has been linked to various athletic injuries[1-9] and proven to be one of the many conditions affected by traumatic brain injury.[10-13] Some investigations have shown that lower extremity fatigue has an adverse effect on postural control. [10,14-18] Special balance tests such as the Balance Error Scoring System (BESS) and Rhomberg's balance test used to evaluate postural control could potentially produce misleading results due to fatigue levels of the athlete.

Postural control or balance has been defined as the act of maintaining, achieving, or restoring a state of balance during any posture or activity.[19] In research and postural assessments, force plates are often used for analysis. Force plates measure ground reaction forces by measuring sway and elliptical velocity, movement on medio-lateral and antero-posterior axes, and center of pressure while standing.

Evidence has shown that injury rates increase as a result of muscle fatigue.[1-9] The return to baseline after anaerobic and aerobic exercise protocols affected postural control up to 13 minutes following exercise.[10]

This investigation identified when it is appropriate to test the postural control of persons with suspected concussions during sports play. A significant difference in postural control at 3 minutes and 8 minutes occurs following fatigue.[10] Studying the effects of time of day on postural control, dynamic postural control is greatest at the start of the day, suggesting that the components of postural control maybe effected by fatigue throughout the day.[7,16] Further research is warranted to investigate the effects of fatigue on postural control.

Purpose of the Study

The purpose of this study was to determine the effects of lower extremity fatigue on postural control with ankle, knee, and hip perturbations.

Hypothesis

It was hypothesized that functional neuromuscular fatigue of the lower extremity would cause a decrease in postural control.

Delimitations

Certain delimitations were set by the investigator of the study, which may have affected the results and conclusions drawn. The study was delimited to the following:

1. Healthy physically active individual's ages 18-30 yrs as defined by the American Heart Association. [22]
2. Subjects without previous history of hip, knee, ankle surgery, or significant lower extremity injury, or head injury.
3. Fatigability of the lower extremity muscles.

4. Evaluation of postural control using the NeuroCom® Equitest® (Clackamas, OR).

## Limitations

The limitations set in this study reflected the effect of the delimitations on the collection and interpretation of data and the ability to expand the scope of sample inference:

1. Beyond the 18-30 y/o healthy age population which will have different postural balance abilities that will differ from a pediatric or geriatric population.
2. Beyond the lower extremity musculature.
3. Beyond the balance assessment capabilties of the NeuroCom Equitest.

## Assumptions

For the purpose of this study, the researcher accepted the following assumptions. It was assumed that:

1. Subjects gave 100% effort during fatigue protocol.
2. Subjects were healthy and answered the health questionnaire and consent form honestly.
3. The athletic maturity and effort of subjects may ave vaired leading to differences in perceived fatigue.

## Significance of Study

Evidence has shown that injury rates increase as a result of muscle fatigue.[1-9] Identifying changes in postural control due to fatigue will allow practitioners to identify prophylactic techniques and exercises that could be used to prevent injuries that are theorized to be caused by fatigue.

Providing such evidence also allows clinicians to be aware of the effect fatigue can have on postural control while conducting sideline postural control exams for suspected concussion immediately after injury. Fox et al. found clinically significant differences in postural control at 3 minutes and 8 minutes following fatigue. [10]

It is important to conduct research on physically active people because they are more likely to engage in strenuous activity to fatigue muscles and engage in high impact sports that could potentially cause a traumatic brain injury. Between 4 and 5 percent of high school and collegiate football players report a concussion each year.[12] In order to accurately assess concussion and determine return to play all components damaged and associated with concussions must be thoroughly examined to minimize possibilities of greater brain damage and second impact syndrome. Postural stability is an important part of the post concussion assessment. Yet, few studies that have conducted balance research using the sophistication of the force plate system provided by the NeuroCom balance systems.

Identifying the effects fatigue may have on postural control can potentially allow practitioners to identify various prophylactic techniques such as bracing and taping that could be used to prevent injuries. Gathering such evidence also allows clinicians to be aware of the affects fatigue can have on balance while conducting sideline postural control exams.

# CHAPTER II

# REVIEW OF LITERATURE

Lower extremity fatigue is a natural phenomenon that occurs in sports participation. Studies have shown that lower extremity fatigue may have an adverse effect on postural control.[10,14-18] Poor postural control has been linked to various athletic injuries and proven to be one of the many aspects affected by traumatic brain injury.[3-9, 10-13] Studies that investigate fatigue and postural control use a variety of balance assessments such as the star balance excursion, Balance Error Scoring System (BESS), and various force plates. A variety of fatigue protocols have also been used to study the effects on postural control. The relationship between lower extremity kinematics, postural control, strength, fatigue, types of injuries, and special test protocols is necessary due to the variation of methods in this research area.

## Lower Extremity Kinematics

Proper lower extremity kinematics is very important during physical activity. There is evidence that indicate fatigue has an adverse effect on lower extremity kinematics and can lead to risk of injury.[23-25] These effects included an increased tibial shear force after landing, increased knee valgus and decreased knee flexion while landing.[23] Studying the effects of fatigue on lower extremity kinematicBenjaminse et al.[24] found that fatigue did alter lower extremity kinematics during a single leg stop jump task. Thirty subjects completed a stop jump task that consisted of a single leg standing jump, followed by a maximal effort vertical jump. Results indicated that subjects had less maximal knee valgus and knee flexion following fatigue. No changes in hip kinematics were observed.

Gribble and Robinson[25] studied the alterations in knee kinematics and dynamic stability associated with chronic ankle stability (CAI). Thirty-eight volunteers performed 10 jump landing task in which ankle plantar flexion, knee flexion, and hip flexion were captured with an electromagnetic device. Results showed that groups with chronic ankle instability landed in less knee flexion. This altered kinematic pattern may alter and influence preventative measures with those who have CAI.

During dynamic activities such as jumping and cutting, different movement patterns occur. These patterns include decreased sagittal plane movement, with joint flexion at the knee, hip and trunk and increased knee valgus and leg rotation. Knee valgus and tibal rotation can increase the load on the anterior cruciate ligament (ACL), thus leading to a greater risk of injury.[3] In a cohort study by Padua et al.,[23] the reliability of the Landing Error Score System (LESS) was examined during jump landing biomechanics. It was determined that those with the lowest scores had greater differences in lower extremity kinematics. The LESS was determined to be a valid and reliable assessment tool in order to identify potentially high risk movement patterns during jump landing.

Postural Control

Postural control or balance is the act of maintaining, achieving or restoring the line of gravity within the base of support.[26] It has also been defined as a function requiring the coordinated activation of joint muscles, visual, and vestibular receptors to maintain the body's center of mass.[27] During sports competitions, a combination of central nervous system inputs is required to perform optimally including components of balance. Postural control is made up of visual, vestibular and sematosensory components. In a study by

Vuillerme et al.,[17] the effect of calf muscle fatigue on postural control during quiet bipedal standing with vision, depends on the eye-visual target distance as the focus of research. In this study, 12 subjects performed a fatigue and no fatigue trial in which vision was absent or present while attempting to maintain postural control. After fatiguing the calf muscles there was decreased postural control during quiet bipedal standing in the absence of vision. This alteration of the sensory proprioceptive and motor systems was used to explain the increased center of pressure along the medio-lateral axis during the no vision trial.[17]

Balance plays an important role in dynamic movement in sports.[26] The central nervous system maintains posture using two components. The first component is sensory feedback organization. The second component is muscle coordination. Muscle coordination includes the sequencing of muscle contractions between the lower extremity and trunk. This is very important in sports activity due to the quick forceful movements. Without the muscle coordination component, such movements would be impossible.

Fatigue

Fatigue can be either central or peripheral depending on which components of the neuromuscular control system are directly impacted.[4] Central fatigue is associated with a lack of motivation.[27] Muscle fatigue has been defined as the reduction in maximal force generating capability during exercises occurring at or distal to the level of neuromuscular junction.[4,27] It is theorized that fatigue may impair the proprioceptive and kinesthetic properties of joints leading to the disruption of afferent feedback loop.[5] The correlation between the fatigue and altered neuromuscular control is that decreased conduction of afferent signals from a fatigued altered state of a muscle will lead to decreased propagation of efferent signals. This will affect compensatory movement.[6] However, whether in the afferent or efferent direction or both motor control will be inhibited by fatigue.[11]

In research, a variety of fatigue protocols have been prescribed in an attempt to find the effects of fatigue on lower extremity postural control. Some include using isokinetic exercises and more functional protools. Examples of isokinetic protocols include the Biodex,[5] Cybex,[11] or the Kin-Com dynamometer.[27] Isokinetic protocols are open kinetic chain exercises that have the ability to isolate specific muscles and provide resistance at a consistent velocity. Some researchers use more functional fatigue protocols. More functional fatigue protocols are more closely related to what may occur during actual sports play. These functional protocols may include a shuttle run,[10] circuit design,[28] or lunge task.[14] Using functional fatigue and isokinetic protocols, researchers have concluded fatigue has an adverse effect on postural control.[10-13]

Fatigue and Injury Rate

Evidence suggests that levels of fatigue increase the likelihood of an injury occurring.[3-9] Gribble et al.[14] studied the effects of fatigue and chronic ankle instability on dynamic postural control in 16 healthy controls and 14 with CAI. Results indicated that the involved side of subject with CAI caused an increase reach distance and knee flexion values. They found that chronic ankle instability and fatigue both disrupted dynamic postural control. One can conclude that disruption of neuromuscular activity caused by the CAI and fatigue the reoccurrence of a lateral ankle sprain is even higher than the average 80%.[14] Weakness or fatigue of the hip abductors or external rotators may add to altered extremity landing kinematics and increase risk of injury.[9] Researching hip abductor fatigue, frontal plane landing angle, and excursion during drop jump, Carcia et al.[9] found that fatigued subjects landed in a greater valgus orientation which increases the risk of injury. Exploring the effects of lower extremity muscular fatigue on motor control performance, Johnston et al.[1] used 20 healthy subjects to complete pre and post-fatigue test. Each individual was fatigued using an isokinetic dynamometer and motor control was tested using an instrumented balance test. Findings indicate that avoidance of fatigue and de-conditioning may prevent injury. Furthermore, a study measuring the effects of ankle fatigue models on the duration of postural control found that the fatigue protocol resulted in impairment of postural stability.[27] It was concluded that the time frame to recovery from fatigue is 2 to 3 minutes, and during this time period, postural stability is compromise and may result in an athletes being more susceptible to injury.[27]

Muscle function around the knee play a role in stability and injury prevention.[27] It can also be assumed that ligamentous laxity caused by muscle fatigue may lead to increased risk of injury.[29] Many studies have found correlations between decision making, fatigue and ACL injuries.[3] Other studies have found that fatigue increases the risk of ACL injuries by promoting extreme lower limb biomechanics stemming from inadequate active joint stabilization by sub-optimal muscle activation due to fatigue.[4]

Gender

Statistics indicate that females are at a high risk for ACL injuries than males.[30] During activities such as jumping and cutting females are 2 to 9 times more likely to tear their

ACL.[30] Gender differences in the sagittal plane and transverse plane motions at the hip and knee are hypothesized to be a potential risk factor for ACL injuries.[23] Women tend to activate muscles in a pattern that favors abduction loading, therefore increasing their chances of ACL injury. Palmieri-Smith et al.[30] studied the association of quadriceps: hamstring cocontraction pattern with knee joint loading. Twenty one active adults performed 3 trials of 100cm forward hops, using electromyographic data from the medial and lateral hamstrings and quadriceps finding a lower cocontraction of muscles was lower in women. It was conclude that medial to lateral quad:hamstring cocontraction was unbalanced in women and may increase the risk of ACL injury. Barett et al.[31] studied the gender differences in the variability of lower extremity kinematics 18 men and 15 women ran at different speeds during treadmill locomotion.

Kinematic data were recorded using an electromagnetic tracking system. They found that the greatest kinematic differences existed when women and men ran at higher speeds. They concluded that this may be due to the degree of biological stress women may sustain while running at higher speeds. Those stresses may lead to a reduction in dynamic degrees which may cause women to be less able to adjust to perturbations at higher speeds.[31]

Postural Control and Concussion

Concussion can be defined as brain injury caused by sudden acceleration or deceleration of the head that results in any immediate, but temporary, alteration in brain function, that may cause loss of consciousness, blurred vision, dizziness, amnesia or memory impairment.[11] Between 4 and 5 percent of high school and collegiate football players report a concussion each year.[13] Areas of the brain damaged as a result of concussion includes neurocognitive as well as maintenance of postural equilibrium.[11] The communication of the visual, vestibular and somatosensory systems may be lost due to a traumatic brain injury and cause postural instability in the anterior posterior direction, medial lateral direction, or both.[32] In order to assure concussion is being evaluated properly objective measures of neurocognitive function and postural control must be assessed. Postural stability is an important part of the post concussion assessment. Standard clinical balance test such as the Rhomberg may not be objective or sensitive enough to identify balance deficits.[26] It is important to thoroughly evaluate all signs and symptoms associated with concussion due to secondary impact syndrome that can occur and be fatal.

Muscular Strength-Squatting Task

A squatting task represents a closed kinetic chain exercise involving the hip, knee and ankle. Agonistic and antagonistic musculature involved with a squat are equally prominent in control and coordination of jump landing tasks similar to that done by Borokatar et al.[3] While studying the combined effects of fatigue and decision-making on female lower limb landing postures, fatigue was induced using repetitive squats and randomly order jump sequences, until subjects could no longer complete three consecutive squats. Bilateral squatting consist of keeping an up right trunk while bending at the knee and hips as if sitting in a chair. Thighs should finish parallel with the floor. In this research fatigue was associated with a significant increase in initial contact hip extension and internal rotation, which may represent a worst case scenario for ACL injury risk.[3]

Unilateral fatigue induces a fatigue cross over to the contralateral limb using a single leg squat fatigue protocol .[17] The point of fatigue was defined when subjects could not complete 3 consecutive squats. Looking at differences in muscle activation during a single leg squat, step over and lunge, there was more muscle activation of the rectus femoris, gluteus maximus, and gluteus medius during performance of a single leg squat.[33] Theory suggests that hip musculature plays a very important role in controlling multiplaner femoral motion during sports.[9] The muscles that surround the hip are of increase interest when referencing lower extremity injuries. Specifically weakness in hip abductor muscles has been observed in patients with patellofemoral pain syndrome, iliotibial band syndrome, anterior cruciate ligament injuries and ankle instability.[33]

Hip abductor muscle weakness can have a major influence on the alignment of the thigh and leg in the frontal plane during activities like climbing stairs, sitting and squatting.[34]

<u>Force Plates</u>

A measurement tool that is most often used to measure aspects of postural control is a force plate. Force plates measure ground reaction forces by measuring sway and elliptical velocity, movement on medio-lateral and antero-posterior axes, and center of pressure while standing. Jump landing vertical, anterior-posterior and medial-lateral ground reaction forces (GRF) were measured using a Bertec tri-axial forceplate, which uses a series of force transducers to record GRF over time.[7] The Chattecx Balance System also measures vertical reaction forces with transducers. This system was used to explore the effects of plantar flexor and dorsiflexor fatigue in unilateral postural control.[8] Harkins et al. used the NeuroCom SMART Balance Master to assess postural control.[27] This system uses a long force plate to measure sway velocity with computerized dynamic posturography (CDP).

<u>Computerized Dynamic Posturography</u>

Computerized dynamic posturography consist of quantifying all three balance components which include visual, vestibular and somatosensory. It quantifies how the body responds to a variety of inputs, movement strategies and motor output mechanisms. This is the only method validated by controlled research studies.[35] During CDP testing, the patient stands on a movable, dual forceplate support surface within a moveable surround (enclosure).

Under control of a computer, the force platform can either move in a horizontal plane (translate), or rotate out of the horizontal plane.[36] Test protocols of CPD are Sensory Organization test (SOT), Motor Control Test (MCT), and Adaptation test (ADT). The SOT disrupts sensory cues by altering visual and sematosensory inputs while measuring maintenance of equilibrium.[11] The MCT assesses the ability of the automatic motor system to quickly recover following an unexpected external disturbance. A patient's ability to adapt to automatic response to minimize sway on irregular surfaces is assessed by the ADT.

The MCT assesses the ability of the automatic motor system to quickly recover following an unexpected external disturbance. Sequences of small, medium or large platform translations (scaled to the patient's height) in forward and backward directions elicit automatic postural responses. Translation of the surface in one horizontal direction results in displacement of the center of gravity (COG) away from the center in the opposite direction relative to the base of support. To restore normal balance, a quick movement of the COG back to the center position is required.

The reliability and validity of the NeuroCom systems has been documented in research studies.[26, 37-38] Liston et al.[37] examined the test-retest reliability and validity of data obtained using the Balance Master (BM), a computerized balance assessment and training tool in stroke patients. Concurrent validity of the BM data was determined using the Berg Balance Scale and gait velocity as criterion standards.

Researchers concluded that in stroke patients the test-retest reliability of data obtained using the BM is greatest for complex tests of balance and that dynamic rather than static balance measures are valid indicators of functional balance performance.[38] CDP was the only test to document significant sensory impairment following mild head injury.

A Systematic Approach to Research

In physically active males and females, aged 18-40, does lower extremity fatigue have an effect on static postural control? Only studies assessing postural control measures in participants that were male and female, physically active, and aged 18-40 were used to answer the above question. Additionally, only studies measuring static balance were used. This excludes articles that solely measured dynamic balance. The investigation focused on lower extremity fatigue and therefore the studies included pertained to at least one muscle group of the lower extremity and excluded articles solely focused on the upper extremity. The search was also narrowed to only articles with a pre-post design or with a control group. The PEDro scale was used to evaluate the included studies.[39]

For the assessment of whether fatigue affects postural control, we calculated effect sizes (Cohen d), based on the data reported in the original articles.[10,15,17-18,40-41] Cohen d values less than 0.4 were interpreted as weak, from .41 to 0.7 as moderate, and more than 0.7 as strong. A 95% confidence interval (CI) was calculated around the point estimates.[42] Additionally, the quality of the evidence was assessed with the Strength of Recommendation Taxonomy (SORT).[43] There are three levels of recommendation for SORT. The first level indicates good quality, patient-oriented evidence; 2 indicates limited quality, patient-oriented evidence; and 3 indicates non-patient-oriented evidence.

The strength of these SORT levels range from A through C, with A indicating that the recommendation was based on consistent and good quality, patient-oriented evidence; B that it was based on inconsistent or limited-quality, patient-oriented evidence; and C that it was based on evidence other than patient-oriented evidence. The SORT level of evidence for the articles reviewed was 2 because the methodologic quality of included articles was not consistently high, with a grade of B due to some inconsistent findings.

Only six articles met the inclusion criteria to answer this question.[10,15,17-18,40-41] The mean PEDro score for these articles was 2.7. Two articles provided sufficient data to allow calculation of effect sizes. The remaining four articles provided their resulting data in graphical representation. Means and standard deviations to calculate the effect sizes could not be determined.

Using 36 collegiate athletes, the return of postural control to baseline after anaerobic and aerobic exercise protocols was adversely affected up to 13 minutes after an aerobic and anaerobic fatigue protocol.[10] Researchers concluded that clinicians should be aware of appropriate times to administer sideline assessments of postural control. The positive effect size indicates an increase in postural control and a negative effect size indicates a decrease in postural control.

At 3 minutes after the anaerobic protocol sway velocity effect size was calculated to be -0.57. Cohen's interpretation of -0.57 is that of moderate effect size. After the aerobic protocol, sway velocity at 3 minutes had an effect size of -0.91, and at 8 minutes at -0.39. Cohen's interpretations of these figures are large and moderate effect size respectively.

Looking at elliptical sway following the aerobic fatigue protocol, effect size was calculated at 3 minutes and 8 minutes, values were -1.35 and -0.56 respectively. Cohen's interpretations of these values are as large effect size and moderate effect size. Following the anaerobic protocol the effect size between baseline and post-elliptical sway was -0.96 at 3 minutes, and at 8 minutes -0.55. Respectively, Cohen's interpretation of these values is large and moderate effect size.

After holding a weight strapped to the foot in order to fatigue the tibialis anterior and peroneus muscles, researchers found that as a result of fatigue, postural sway was increased using a KISTLER forceplate.[41] The results of the effect size analysis were not consistent. The point estimates ranged from -2.73 to 0.12. The positive effect size indicates an increase in postural control and a negative effect size indicates a decrease in effect size. Although a majority (15 out of 18) of the effect sizes was negative, 12 had confidence intervals that crossed zero.

## Conclusions and Summary

After review of literature and systematic review many conclusions can be made. One may conclude that there is substantial evidence that supports the idea that fatigue does cause postural control deficits. Clinical significance that supports the idea that lower extremity muscular fatigue did have an adverse effect on postural control.[10,41] Although clinical significance was found, confidence intervals revealed insignificant data. Identifying significant differences of fatigue on postural control may allow practitioners to identify various prophylactic techniques that could be used to prevent injuries.

Gathering such evidence would also allow clinicians to be aware of the effects fatigue can have on balance while conducting sideline postural control exams. Further research therefore is necessary to support current findings that explore the effects of fatigue on postural control.

# CHAPTER III

# METHODOLOGY

The purpose of this study was to determine the effects of lower extremity fatigue on postural control in physically active males and females. In this chapter subjects are described as well as test and instruments used, procedures, and design analysis.

## Setting

The testing was performed during one session in a controlled laboratory at Texas State University-San Marcos. Participants completed all activities in the Athletic Training Research Laboratory.

## Subjects

Thirty healthy and physically active individuals were used for this investigation 18 females and 12 males. Recruited subjects had no previous history of hip, ankle, knee surgery or significant lower leg injury. Subjects were excluded from this investigation if they had a current upper respiratory illness or sustained an injury within the previous two months of the hip, ankle, or knee. Each subject was required to complete and sign an informed consent (Appendix A). Demographic information such as height, weight, and age was assessed using a health questionnaire (Appendix B) designed to evaluate physical status and health history.

Range of motion, strength, and laxity of the lower extremity was assessed by a licensed health care provider. The health questionnaire contained a unique number ID which was issued to each participating subject to maintain confidentiality of the subject. This form was evaluated by a licensed health care provider. Incentives for participation include knowledge of physiological feedback which include, fatigue levels and neurological response.

Subject number was estimated using the effect size found in previous research.[10] A significant difference existed in postural control after fatigue at 3 minutes and 8 minutes following fatigue protocol.[10] All research was evaluated for effect size, which evaluates magnitude of an experiment treatment or size of the effect. The greater the effect size the greater the magnitude on the treatment response. In this particular study, effect size was calculated between baseline sway velocity and elliptical sway and post exercise sway velocity and elliptical sway velocity. Means and standard deviations were used to calculate the effect sizes using Cohen's D effect size calculator[42].

Possible risks of the study included possible delayed onset muscle soreness as a result of performing multiple bilateral squats. Slight dizziness or imbalance may have occured while completing the Motor Control Test (MCT) of the Equitest. To Ensure safety of subjects a safety harness was worn as well as a trained assistant at the side of the subject.

Subjects were recruited using flyers displayed in the Jowers Center at Texas State University-San Marcos. Physically active individuals were defined by the American Heart Association.[15]

The American Heart Association describes being physically active for adults aged 18-65 years of age, as performing moderate intensity aerobic physical activity for a minimum of 30 min on five days of the week. Moderate intensity exercise is equivalent to a brisk walk in which the heart is elevated. The level of athletic ability and maturity (i.e., competitive level) between subjects may have differed with age and experience. All subjects engaged in pre and post treatment; however sequence of treatment was randomly assigned. Health history of all subjects was thoroughly reviewed to ensure safety.

The Institution Review Board (IRB) at Texas State University-San Marcos reviewed all methods and a legal form was signed by the principle investigator as well as the subject in order to assure the safety of the subject (Appendix A). Any indication of possible health problems that may have compromised subject safety or the validity of the study constituted grounds for exclusion.

Test and Instruments

Postural control was measured using the Neurocom Equitest® Balance Assessment System (Clackamas, OR), the world leader in the development of computerized tools for the assessment and rehabilitation of patients with balance and mobility disorders. Subjects were asked to stand on the force plate of the Equitest, and a MCT was performed and analyzed.

The Equitest system utilizes a dynamic force plate with rotation and translation capabilities to quantify the vertical forces exerted through the patient's feet to measure center of gravity position and postural control; and a dynamic visual surround to measure the patient's use of visual information to maintain balance.[44]

It provides assessment capabilities on either a stable or unstable support surface and in a stable or dynamic visual environment.

The MCT assesses the ability of the automatic motor system to quickly recover following an unexpected external disturbance.[45] Sequences of small, medium or large platform translations (scaled to the patient's height) in forward and backward directions elicit automatic postural responses. Translation of the surface in one horizontal direction results in displacement of the center of gravity (COG) away from the center in the opposite direction relative to the base of support.

To restore normal balance, a quick movement of the COG back to the center position is required. Fatigue will be induced by having the subject performed repetitive bilateral squats using body weight. The point of fatigue was defined when the subject cannot perform three consecutive squat unassisted.[3]

Procedures

When cleared for participation, each subject received a thorough explanation of the experimental procedures before commencing the treatment. All subjects wore clothing that was appropriate for completing a 5 minute stationary bike warm up, repetitive bilateral squat and maintaining balance.

Permission to conduct this study was received from the Human Review committee at Texas State University. An informed consent was signed by all participants (Appendix A). Step by step data collection procedures was used and described to all subjects (Appendix C).

Warm-up

Subjects completed a 5-minute warm-up on an indoor cycle bike followed by performing static stretches of the hip flexors, quadriceps, hamstrings and gastrocnemius. After completing the warm-up subjects were asked to remove shoes in order to decreases time between the fatigue protocol and motor control testing.

Baseline Testing

A safety harness provided by NeuroCom Equitest was placed on each subject to analyze baseline postural control. The safety harness remained on throughout data collection in order to minimize time between fatiguing the subject and analyzing postural control. A pre-fatigue baseline motor control test MCT using the Equitest was taken from each subject immediately before fatiguing the lower extremities. After the baseline MCT, the subject randomly selected three time intervals from an envelope that determined the order in which postural control was tested.

Fatigue Protocol

Fatigue was defined at the point in which the subject could no longer do three consecutive squats unassisted. Each subject performed repetitive bilateral squats using body weight. The principle investigator enforced that the thighs finish parallel to the ground at the end of each squat using verbal commands. When the subject could no longer do 3 consecutive squats the stop watch started. The fatigue protocol was repeated between each trial.

Post-Fatigue Trial 1

A stop watch began immediately at the time of fatigue protocol completion. Subjects were placed on the NeuroCom immediately at the time of fatigue at zero minutes to complete postural control testing. At a time interval of 5, 10 or 15 minutes which was previously determined, the subject was then placed on the Equitest again to complete the post-fatigue MCT trial. After the post fatigue MCT was complete subjects rested for 4 minutes to minimize the effects of repetitive neuromuscular fatigue.[46] Rest included spinning on the indoor cycle bike. After rest the fatigue protocol was completed.

Post Fatigue MCT Trials 2 and 3

At one of the two remaining time intervals the subject was placed back on the Equitest for the post-fatigue MCT analysis. After the post fatigue MCT was complete subjects rested for 4 minutes to minimize the effects of repetitive neuromuscular fatigue. At this point subjects repeated the fatigue protocol and post-fatigue testing until postural control at all three time intervals had been tested.

Cool Down

When all three remaining time intervals had been completed the subject engaged in a cool down. The cool down consisted of spinning on the bike for five minutes followed by stretching of the lower extremities to reduce possible risk of delayed onset muscle soreness.

Design Analysis

The dependent variable for this study was postural control using the MCT score of the NeuroCom Equitest. The independent variables for this study were gender, and the pre- and post- fatigue trials. Fatigue was defined by the inability to complete three consecutive bilateral squats using body weight. The post fatigue time intervals were conducted immediately after fatigue at 0 minutes, 5 minutes, 10 minutes, and 15 minutes. Data analysis was performed using repeated measures ANOVA and paired t-test for pre and post fatigue composite latency scores. Stata – version 11 (StataCorp LP, College TX) was used to calculate the statistical analyses. For the assessment of whether fatigue had significant effects on postural control, we calculated effect sizes (Cohen d). The effect sizes were interpreted using the guidelines described by Cohen.[42] Demographic information was analyzed using central tendency scores (means, range, standard deviation) from pre-test data generated from the health questionnaire (Appendix B). These variables were compared to determine the relationship between lower extremity fatigue and postural control using the Equitest. Alpha was set at a $p < 0.05$ level of significance on all analysis.

# CHAPTER IV

# MANUSCRIPT

Key Words: bilateral squat, exercise, motor control, hamstring, quadriceps

## Introduction

Lower extremity fatigue is a natural phenomenon that occurs in sports participation. It has been linked to increased injury rates as well as poor postural control.[1-9] When looking at postural control one must consider the musculature that is involved with stability and maintaining control. The musculature surrounding the knee plays an important role in stability and injury prevention.[27] The quadriceps and hamstrings are two major muscles that surround the knee and aid in stability. Fatigue has been shown to increases the risk of ACL injuries by promoting extreme lower limb biomechanics stemming from inadequate active joint stabilization by sub-optimal muscle activation which may be the result of fatigue.[4] Lower extremity fatigue does adversely effect postural control.[10,14-18] Postural control has been proven to be one of the many aspects affected following traumatic brain injury.[10-13] While assessing postural control following traumatic brain injury balance tests, such as the Balance Error Scoring System (BESS ) and Rhomberg's balance test occasionally produce misleading results due to fatigue levels.[10, 26] Annually, between 4 and 5 percent of high school and collegiate football players report a concussion.[12]

Areas of the brain damaged as a result of concussion include neurocognitive as well as maintenance of postural equilibrium.[2] In order to assure a concussion is being evaluated properly, objective measures of neurocognitive function and postural control in the fatigued individual must be assessed. Previous research has failed to provide evidence of this using the sophistication of computerized dynamic posturography. Previous research has failed to identify differences in postural control following fatigue whichmay aid in identifying proper times to evaluate postural control post injury. The purpose of this study is to explore the effects of neuromuscular fatigue on postural control with perturbations over time in physically active individuals.

Methods

Thirty physically active males and females (age=22±2.54 yrs, height=166.77±8.59cm, weight = 65.51± 3.01kg) volunteered to participate in this investigation. Physically active individuals were defined by the American Heart Association as performing moderate intensity aerobic physical activity for a minimum of 30 minutes on five days of the week.[22] Before testing began each subject was required to complete and sign an informed consent (Appendix A). Demographic information such as height, and age was assessed using a health questionnaire designed to evaluate physical status and health history (Appendix C). Range of motion, strength, and laxity of the lower extremity was assessed by a licensed health care provider. Subjects were excluded if they had a current upper respiratory illness or sustained an injury within the previous two months of the hip, ankle, knee or significant lower leg injury.

All subjects were warned about possible risks which included delayed onset muscle soreness and dizziness. This study was approved by Texas State University-San Marcos Institutional Review Board (Appendix A).

Instrumentation

Postural control was measured using the Neurocom Equitest Balance System (NeuroCom International, Inc., Clackamas, OR) utilizing a dynamic dual force plate system with rotation and translation capabilities.[44] Subjects were asked to stand on the force plate of the NeuroCom Equitest, and a Motor Control Test (MCT) was performed and analyzed. The NeuroCom Equitest provides balance assessments on either a stable or unstable support surface and in a stable or dynamic visual environment.

The MCT assesses the ability of the automatic motor system to quickly recover following an unexpected external disturbance.[45] Anterior or posterior translation of the surface in one horizontal direction results in displacement of the center of gravity (COG) away from center in the opposite direction relative to the base of support.

Procedures

When cleared for participation, each subject received a thorough explanation of the experimental procedures before commencing the treatment. All subjects wore clothing that was appropriate for completing a warm up, and repetitive bilateral squat without constraining balance. Subjects completed a five minute warm-up on an indoor cycle bike followed by performing static stretches of the hip flexors, quadriceps, hamstrings and gastrocnemius.

After completing the warm-up subjects were asked to remove shoes in order to decrease time between the fatigue protocol and MCT. A safety harness provided by NeuroCom Equitest was placed on each subject throughout the entire testing period. A pre-fatigue baseline MCT using the NeuroCom Equitest was taken from each subject immediately before fatiguing the lower extremities. After the baseline MCT, the subject randomly pulled three time intervals from an envelope that determined the order in which postural control was tested.

Each subject performed repetitive bilateral squats using body weight. Fatigue was defined at the point in which the subject could no longer do three consecutive squats unassisted. Squats were completed to the beat of a metronome set at 60 beats per minute. The principle investigator enforced that each subject's thighs finish parallel to the ground at the end of each squat using verbal commands. The stop watch began immediately at the time of fatigue to determine the time period between fatigue protocol and balance assessment. Subjects were placed on the Equitest immediately (zero minutes) at the time of fatigue to complete postural control testing. At a randomly assigned time interval of 5, 10 or 15 minutes, which was previously determined, the subject was placed on the NeuroCom Equitest to complete a post fatigue MCT. After each post fatigue MCT was complete, subjects rested for at least 4 minutes to minimize the effects of repetitive neuromuscular fatigue. When all three remaining time intervals were completed, the subject engaged in a cool down. The cool down consisted of spinning on the bike for five minutes followed by stretching of the lower extremities to reduce possible risk of delayed onset muscle soreness.

Statistical Analysis

Demographic information for 30 subjects was analyzed using central tendency scores (means and standard deviation) from pre-test data generated from the health questionnaire. Dependent variables included pre-test and post-fatigue composite latency scores at zero, five, ten, and fifteen minutes. These post-fatigue trials were compared to pre-fatigue latency scores using repeated measures anova. Significant levels were set at $p \leq 0.05$ for all analysis. Stata– version 11 (StataCorp LP, College Station, TX) was used to calculate all statistical test. Effect size was calculated using Cohen's d. Values less than 0.4 were interpreted as weak, from 0.41 to 0.7 as moderate, and more than 0.7 as strong. A 95% confidence interval (CI) was calculated around the point estimates. Higher latency scores indicate slower response to external disturbance.

Results

Repeated measures ANOVA revealed a significant gender effect, $F(1,28) = 12.3$, $p = 0.002$, was observed across all trials. Males (134.2 ± 12.7) scored higher overall than females (123.0 ± 7.4) on the balance tests. There was a moderate effect size between males and females. Effect size with the confidence interval set at 95% was 0.47. No differences in postural control were observed across various trials $F(4,112)=1.3$, $p=0.264$. The mean number of squats at zero minutes was 153±3.4, at five minutes 150±5.67, at ten minutes 149±4.32 and at fifteen minutes 147 ±2.5. The mean score of post-fatigue test latency scores at zero minutes (127.23 ± 10.31), at five minutes (127.3±10.31), at ten minutes (127.3±12.66) and at fifteen minutes (129±12.50) was greater than the mean pre-fatigue latency scores (126.3 ± 9.03). Effect sizes with the confidence interval set at

95% ranged from (0.096-0.251) indicating a weak level of clinical significance across pre and post trials (Table 1).

Table 1. Demographic Information and Mean Latency Scores

| X | Baseline Testing Pre-Fatigue Latency | Post-Fatigue Latency at 0 min | Post -Fatigue Latency at 5 min | Post-Fatigue Latency at 10 min | Post-Fatigue Latency at 15 min |
|---|---|---|---|---|---|
| **Mean** | 126.30 | 127.23 | 127.33 | 127.30 | 129 00 |
| **Standard Deviation** | 9.03 | 10.31 | 11.84 | 12.65 | 12.50 |
| **Cohen's d** | | 0.096 | 0.099 | 0.090 | 0.251 |
| **Squats Until Fatigue** | | 153±3.4 | 150±5.67 | 149±4.32 | 147±2.5 |

Discussion

The purpose of this investigation was to determine the effects of lower extremity fatigue on postural control with ankle, knee, and hip perturbations in physically active individuals. It was hypothesized that functional neuromuscular fatigue of the lower extremity would cause a decrease in postural control. This study found no differences in postural control between pre-fatigue and post-fatigue protocols. These findings contradict a study by Fox et al.[10] who found that fatigue affected postural control up to 13 minutes following aerobic and anaerobic exercise. Furthermore, measuring the effects of ankle fatigue models on the duration of postural control found that fatigue created impairment in postural stability.[27] This too contradicts the findings of this current investigation. Differences between this study and previous research may be due to variations in methodology, for example fatigue protocols and postural control assessments. The fatigue protocol of this study consisted of bilateral bodyweight squats until the point of fatigue; when the subject could no longer complete three consecutive squats. In comparison, Fox et al. used a functional fatigue protocol that consisted of repeated shuttle runs and maximal effort sprints.[10] Johnston et al. used an isokinetic dynamometer to induce fatigue. Both of these studies found that fatigue adversely affect postural control. Postural control was also assessed in this investigation using the MCT of the NeuroCom Equitest. Other studies used a variety of balance assessments including the BESS[10], KAT instrumented balance assessment system,[2] and Chattecx Balance System.[17] These studies also found that fatigue adversely effect postural control. There was a significant gender effect. Height differences in males and females could be the cause; however, more research is warranted.

Fatigue did not affect postural control in this study possibly due to a number of reasons. One reason may be due to the fact that lower extremity fatigue was the focus versus whole body fatigue. The MCT implements ankle and knee perturbations; however, the ankle musculature was not fatigued. After the small, medium, or larger translation, the person must recover using the entire body. The entire body was never in a state of fatigue. Subjects could have possibly used the rest of their body to compensate for the hamstring and quadriceps fatigue thus producing latency values within normal limits. Subjects also completed the MCT five times during one testing period in the exact same sequence. There may have been a learned effect. Anticipating the different translations could have lead to normal latency scores. The MCT looks at the response of two legs together versus single leg stance. This allows for compensation between the two legs, which could allow subjects to regain balance after the external disturbance and produce normal latency cores.

Conclusion

There were no differences found between pre fatigue and post fatigue trials contrary to the hypothesis in this investigation. The mean latency scores did not illustrate that muscular fatigue has an effect on postural balance or control.

Future research using different fatigue protocols as well as postural control assessments should be carried out in order support previous research that yields evidence of decreased postural control following fatigue.

# CHAPTER V

# CONCLUSIONS, APPLICATIONS AND RECOMMENDTATION

## Conclusions and Applications

The purpose of this study was to determine the effects of lower extremity fatigue on postural control with ankle, knee, and hip perturbations in physically active individuals. It was hypothesized that functional neuromuscular fatigue of the lower extremity would cause a decrease in postural control. This investigation found no difference in postural control as the result of lower extremity muscular fatigue.

## Recommendations

Different fatigue protocols and balance assessment tools should be investigated to study the effect of fatigue on postural control. It is clear that muscle fatigue as investigated in this study does not adversely affect postural control.

The MCT has been validated to assess the ability of the automatic motor system following an unexpected external disturbance.[45] This particular test may not have been sensitive enough to find differences following repetitive body weight squats. The present study investigated a functional fatigue protocol in relationship to postural control. No differences were observed amongst various trials between pre and post fatigue trials. Subjects were tested using the MCT at a pre-fatigued state and post-fatigue state at zero minutes, five minutes, ten minutes, and fifteen minutes.

These time intervals could have been too long and may need to be adjusted for future research. The results may have been altered due to fatiguing multiple muscles of the hip instead of isolating one muscle. Isolation of one muscle may have produced more objective data. There also could have been a learned effect. Testing could possibly be divided over a period of time to minimize any possibilities of a learned effect. Using different balance assessments such as video or EMG could possibly yield different or more accurate results. Further research is warranted in order to explore different combinations of fatigue protocols and postural control assessments.

# APPENDIX A

## CONSENT FORM

Participation in Effects of Lower Extremity Fatigue on Postural Control with Perturbations Over Time in Physically Active Males and Females

Department of Health and Human Performance, Texas State University

The principal investigator is Derica Nealy. The researcher can be contacted by email, dn1058@txstate.edu, or phone, (817) 692-3091. Supervising faculty, Dr. Jack Ransone, Department of Health and Human Performance can be contacted by phone at (512) 245-8176 or email at ransone@txstate.edu.

**INTRODUCTION AND PURPOSE OF STUDY**

You have been asked to participate in a study to assess your standing postural control using a forceplate system. The investigation will help to determine if fatigue of hamstring and quadriceps muscles will lead to deficits in postural control over time. One session of testing will last approximately 90 minutes. Sessions will be scheduled at the convenience of all participants. You will be evaluated in the Athletic Training Research Lab in the Jowers building, room D108 at Texas State University.

The following form includes more details regarding the research if you have any questions or concerns about the study please ask before you decide to participate.

**STUDY PARTICIPATION**

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at anytime without penalty and without loss of benefits to which you are otherwise entitled, Department of Health and Human Performance and Texas State University. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed. If you have any other questions regarding the research, research participants' rights, and/or research-related injuries to participants please contact the IRB chair, Dr. Jon Lasser, (512) 245- 3413, lasser@txstate.edu or to Ms. Becky Northcut, Compliance Specialist, (512) 245 2102.

**MOTOR CONTROL TESTING**

The EquiTest® assesses balance control and postural stability. The Motor Control Test (MCT) determines the ability to quickly recover balance following a sudden movement of the forceplate forward and backwards. The forceplate is a metal plate that sits on the floor of the Neurocom. The forceplate can move forward and backwards. Standing in the Neurocom on the forceplate is similar to standing in a corner. Sequences of small, medium or large platform movements in forward and backward directions will be experienced while standing to determine how well one can recover following a sudden movement. A safety harness will be worn to decrease risk of fall down.

The safety harness is a vest that closes in the front with buckles.

It will be attached to the Neurocom with two straps. In the event of a fall the straps will serve as support preventing a fall.

**PROCEDURES**

All subjects will wear clothing that is appropriate for completing a 5 minute stationary bike warm up, stretching, repetitive bilateral squat and maintaining balance. This includes a t-shirt, athletic shorts, and tennis shoes. Athletic clothing is required in order to meet range of motion requirements while performing a squat.

1. Subjects will be asked to warm up five-minutes on an indoor stationary cycle bike followed by performing static stretches of the hip flexors, quadriceps, hamstrings and gastrocnemius.

2. Subjects will be asked to remove shoes in order to decrease time between fatigue protocol and motor control testing.

3. A safety harness will be placed on each subject provided by Equitest®.

4. Each subject will stand on the forceplate to complete a pre-fatigue baseline Motor Control Test (MCT) using the Equitest. This will be taken from each subject before post-fatigue trials.

5. After baseline MCT the subject will randomly draw three time intervals (5, 10, 15 tested.

6. The subject will then be asked to perform full repetitive bilateral squats to the point of fatigue using body weight, enforcing that the thighs finish parallel to the ground at the end of each squat. Fatigue will be defined when the subject can no longer do three consecutive squats unassisted.[4]

7. A stop watch will be started when the subject reaches fatigue and subjects will immediately get on the Equitest foreplate to complete a post-fatigue MCT.

8. When the stop watch reaches 5, 10 or 15 minutes of time which will be previously randomly selected from an envelope the subject will perform another post-fatigue MCT.

9. After the post-fatigue (MCT) is completed the subject will rest for at least 4 minutes in order minimize the effects of repetitive neuromuscular fatigue between trials. Rest will include spinning on an indoor cycle bike.

10. The subject will then be asked to perform full repetitive bilateral squats using body weight, enforcing that the thighs finish parallel to the ground at the end of each squat.[4]

11. When the subject cannot complete three consecutive squats unassisted they will be placed back on the Equitest® after one of the two remaining time intervals (5, 10, or 15 minutes) to perform a post-fatigue (MCT). Time will be recorded using a stop watch.

12. After the post-fatigue (MCT) is completed the subject will rest for at least 4 minutes in order to minimize the effects of repetitive neuromuscular fatigue.

13. Steps 10-12 will be repeated until MCT at all three time intervals (5, 10 and 15 minutes) have been completed.

14. Each subject will complete a total of five Motor Control Tests. One pre-fatigue and four post-fatigue.

15. Pre-fatigue and post-fatigue results will be taken for analysis.

16. When all three time intervals have been completed subject will engage in a cool down. The cool down will consist of spinning on the bike for five minutes followed by stretching of the lower extremities to reduce possible risk of delayed onset muscle soreness.

**POTENTIAL RISKS AND DISCOMFORTS**

The potential risks for this experiment are minimal because the participants will be supervised by the principal investigator during the duration of the study. Minor discomforts may be experienced due to the fatigue phase of the experiment. Delayed onset muscle soreness will last 24 to 48 hours and can be relieved with over the counter non-steroidal anti-inflammatory drugs. Risks will be minimized by warming up prior to fatigue protocol and cool down afterwards. Other risks include the possibility of some feelings of slight dizziness or imbalance during the balance testing. To ensure your safety, you will wear a safety harness during the standing tests with a trained assistant at your side. The safety harness is a vest that closes in the front with buckles. It will be attached to the Neurocom with two straps. In the event of a fall the straps will serve as support preventing a fall.

In addition, we will be able to stop any tests if you ask us to or if we see that a test appears uncomfortable to you. If excessive pain exists the Texas State University Health Center should be contacted at (512)245-2167 or for emergencies contact 911. Participants are responsible for all medical bills in the event of injury or medical attention is needed as a result of participation in this research.

**POSSIBLE BENEFITS**

The results from this investigation may help you learn about:

1. Knowledge of postural control analyzed by the Motor Control Test.

2. Personal limits of lower leg extremity fatigue will be determined as defined by bilateral body weight squats.

**CONFIDENTIALITY**

Each subject in this study will be issued a participant identification number to differentiate the results found between subjects and protect the subject personal identity. Name, social security numbers, telephone numbers, etc. are not required for testing. Results from the study may be shared for future research except for the consent forms. If consent form material is needed for research purposes the subjects will be contacted for additional written consent for release of their information.

To access the results participants may contact the principal investigator by email dn1058@txstate.edu or by phone (817)692-3091. All recorded data will be kept for a minimum of 3 years, and will be kept in the principal investigator's locked office in a locked cabinet in the athletic department.

**AUTHORIZATION**

The Athletic Training Program supports the practice of protection for human subjects participating in research and related activities. The consent form is provided so that you can decide whether you wish to participate in the present study.

"I have read the above statement and have been fully advised of the procedures to be used in this project. I have been given sufficient opportunity to ask any questions I had concerning the procedures and know that I am free to ask questions as they may arise. I likewise understand that I can withdraw from the study at any time without being subjected to the Athletic Training Program or Texas State University."

Contact Derica Nealy, principal investigator at (817) 692-3091 or email at dn1058@txstate.edu Contact Dr. Jack Ransone, supervising faculty at (512)-245-8176 or email at ransone@txstate.edu if you have any questions.

_______________________________________ ________________

Participant Name Printed (18 years or older) Phone #

_______________________________________

Signature

_______________________________________

Principal Investigator Signature

## APPENDIX B

## MEDICAL HEALTH QUESTIONNAIRE

| **Activity Level** | YES | NO |
|---|---|---|
| Have you ever played sports? | If so what and When? | |
| Are you physically active? | Please list all activities you do for physical activity: | |
| Do you run or walk for 30 minutes at least 3 times per week? | | |
| Do you lift weights? If so how many per week? | | |
| **Current symptoms** | | |
| Do you have any respiratory disorders? i.e. Asthma | If so please list: | |
| Have you experienced chest discomfort with exertion? If so how long ago? | Explain? | |
| Do you experience unreasonable shortness of breath or unusual fatigue while engaging in physical activities? | Explain? | |
| Have you had any lower extremity injuries (hip, knee, and ankle) in the past 6 months? | Explain? | |
| Have you been told by a physician or health care provider not to exercise? | Explain? | |
| Strength, Flexibility, ROM Review | PASS | FAIL |

Emergency Contact: Name__________________Phone Number____________________

I certify that the information included on this form is correct.

| | |
|---|---|
| Participant (Please Print) | Witness (Please Print) |
| Participant (Signature) | Witness (Signature) |
| Date | Date |

# APPENDIX C

## DATA COLLECTION

1. Step by Step Procedures for DATA COLLECTION

2. Go over consent form in its entirety and sign. See APPENDIX AGo over health questionnaire form in its entirety and sign. See APPENDIX B

3. Issue subject ID and complete demographic information

Date:______________

Subject ID #________

Sex______________

Date of Birth_____________

Height__________

Number of Hours of Sleep_______________

4. Explain the research in its entirety.

5. Ask subject if they have any questions

6. Warm-up for 5 minutes on the indoor cycle bike.

7. Complete static stretches of the hip flexors, quadriceps, hamstrings and gastrocnemius instructed by the primary investigator.

8. Subjects will be asked to remove shoes in order to decrease time between fatigue protocol and motor control testing.

9. A safety harness will be placed on each subject provide by Equitest®.

10. A pre-fatigue baseline Motor Control Test (MCT) using the Equitest will be taken from each subject before post-fatigue trials.

11. After baseline MCT the subject will randomly draw three time intervals (5, 10, or 15 minutes) from an envelope that will determine the order in which motor control will be tested.

THE ORDER OF THE MCT SEQUENCE IS RECORDED HERE.

1st__________

2nd___________

3rd_____________

12. Demonstrate full bilateral squat and then have subject practice bilateral squat no more than three times.

13. The subject will then be asked to perform full repetitive bilateral squats using body weight, enforcing that the thighs finish parallel to the ground at the end of each squat. Using verbal commands: "Keep going , keep going " and "Come back up". Fatigue will be defined when the subject can no longer do three consecutive squats unassisted.[4]

THE NUMBER OF BILATERAL SQUATS UNTIL FATIGUE IS RECORDED HERE:

FATIGUE 1

___________A stop watch will be started when the subject reaches fatigue and subjects will immediately get on the Equitest to complete a post-fatigue MCT.

IMMEDIATE MCT PERFORMED (Check for yes) ____________

14. When the stop watch reaches 5, 10 or 15 minutes of time which will be previously randomly selected from an envelope the subject will perform another post-fatigue MCT.

TIME INTERVAL 1 ___________ WAS MCT PERFORMED (Check for

Yes)________________

15. After the post-fatigue (MCT) is completed the subject will rest for at least 4 minutes (spinning on indoor cycle bike)in order minimize the effects of repetitive neuromuscular fatigue between trials.[46]

REST TIME RECORDED HERE_________________________

16. The subject will then be asked to perform full repetitive bilateral squats using body weight, enforcing that the thighs finish parallel to the ground at the end of each squat. Using verbal commands: "Keep going , keep going " and "Come back up".

THE NUMBER OF BILATERAL SQUATS UNTIL FATIGUE IS RECORDED HERE:

FATIGUE 2___________

17. When the subject cannot complete three consecutive squats unassisted they will be placed back on the Equitest® after one of the two remaining time intervals to perform a post-fatigue (MCT). Time will be recorded using a stop watch.

TIME INTERVAL 2 _______WAS MCT PERFORMED (Check for Yes)_____

18. After the post-fatigue (MCT) is completed the subject will rest for at least 4 minutes in order minimize the effects of repetitive neuromuscular fatigue.

REST TIME RECORDED HERE_________

19. The subject will then be asked to perform full repetitive bilateral squats using body weight, enforcing that the thighs finish parallel to the ground at the end of each squat. Using verbal commands: "Keep going , keep going " and "Come back up".

THE NUMBER OF BILATERAL SQUATS UNTIL FATIGUE IS RECORDED HERE:

FATIGUE 3___________

20. When the subject cannot complete three consecutive squats unassisted they will be placed back on the Equitest® after one of the two remaining time intervals to perform a post-fatigue (MCT). Time will be recorded using a stop watch.

TIME INTERVAL 3 ____________ WAS MCT PERFORMED (Check For Yes)________________

21. Pre-fatigue and post-fatigue results will be taken for analysis.

22. When all three time intervals have been completed subject will engage in a cool down. The cool down will consist of spinning on the bike for five minutes followed by stretching of the lower extremities to reduce possible risk of delayed onset muscle soreness.

23. Thank you for your participation in my thesis study.

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