EFFECTS OF LEVEL OF MULTIPLE SCLEROSIS INVOLVEMENT ON

BIOMECHANICS OF SIT-TO-STAND

by

RYAN PATRICK THOMPSON

(Under the Direction of Kathy Simpson)

ABSTRACT

The purposes of the study were to describe the mechanics of the sit-to-stand as performed by individuals with multiple sclerosis (MS), and to determine how the level of MS involvement influences movement and muscle activation strategies selected during standing. Eleven participants were divided into three MS involvement groups, based on the Expanded Disability Status Scale: very mild (0.5-3.0), mild (3.5-4.5), and moderate (5.0-6.0); (n = 6, 3, and 2, respectively). Participants performed six trials of the sit-to-stand movement. Group differences for two-dimensional kinematic, ground reaction force and electromyographic variables were determined using the Kruskal-Wallis test (α = 0.05). No statistical differences were detected, likely due to high intra- and inter-individual variation and small sample size. As a group, the MS participants showed common strategies for muscle activation and control of joint extension velocities. The moderate MS group times during phases were comparable to other neurological populations.

INDEX WORDS: Sit-to-Stand, Multiple Sclerosis, Wavelets, Electromyography, Kinematics, Ground Reaction Force
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B.S., Central Missouri State University, 2001

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment
of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA
2007
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August 2007
DEDICATION

To my mother, father, brother and my fiancé.

“If I have seen further it is by standing on the shoulders of giants. “
Isaac Newton
ACKNOWLEDGEMENTS

I wish to thank Jae Pom Yom, Petur Sigurdsson, Yang-Chieh Fu, Tom Dpiiro and Dr. Ming Lai for their assistance in conducting the study. I would also wish to thank the Athens Chapter of the National MS Society for their participation and enthusiasm during recruitment.
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CHAPTER 1

INTRODUCTION

MS Description

Multiple sclerosis (MS) is an extremely debilitating, but common, medical condition. MS affects approximately 400,000 Americans, with 200 new individuals diagnosed each week (nationalmssociety.org 2005). Individuals with MS are typically diagnosed between the ages of 20 and 50 years. Therefore, MS is the primary neurological disorder affecting young people, particularly women, according to the National Multiple Sclerosis Society (nationalmssociety.org 2003).

It is not surprising, then, that the financial cost to the individual and to society, also, is substantial (Schapiro 2003). Annual healthcare costs in the United States for all people with MS are $13 billion (nationalmssociety.org 2003; Murray 2006). Taxpayers fund approximately $250 million of this cost through government outpatient healthcare programs, such as Medicare/Medicaid, which pays a maximum of $1,740 of costs per year per person (Carolina 1994; Schapiro 2003). The rest of the costs are borne by the patients’ families and their insurance companies.

In terms of the non-financial effects on the individual, MS is a degenerative disease of the CNS. The disease is characterized by lesions/plaque that demyelinate the axons of neurons that connect with other neurons within the CNS and within the motor neurons of the peripheral nervous system. The role of an axon is to conduct action potentials from the neuron’s nucleus to
the dendrites of the next neuron. Thus, the transmission of signals from the demyelinated interneuron axons to the associated motor neurons become disoriented and erratic (Schapiro 2003). Lesions/plaque also cause decreased magnitudes of transmission impulses and conduction velocity of the electrical signal along the affected axons (Schapiro 2003). Without correct excitatory and inhibitory activity of these interneurons modulating motor control of voluntary muscles, voluntary motor control is disrupted. Thus, functional impairment results.

Being able to appropriately contract muscles to accomplish some task (e.g., flex the elbow smoothly) is complex. The central nervous system (CNS) stimulates and modulates electrical activation of appropriate motor neuron synergies. At the motor neuron level, accomplishing the task is dependent on many factors, including the number of motor units activated, the sequencing of the electrical stimulation by involved motor units, inhibition of antagonistic muscle firing and muscle fiber types of activated motor units (Kandel 2000). Thus, when lesions/plaque exist on neurons involved at any level of motor control, signals to affected motor units become disrupted (Kandel 2000). As a result, loss of voluntary motor control and coordination can occur. MS’s degenerative affects on voluntary control also cause limb weakness, fatigue and spasticity (Kandel 2000). Thus, it is apparent that movement can be mildly to severely compromised.

Progressively, involuntary muscles are also affected, leading to problems such as bladder incontinence or vision problems. These other complications, such as visual acuity decrements, can also increase the difficulty of producing effective and/or safe movements. As more neurons become affected, the direct complications that arise from MS increase in the number of organs affected and in severity. The result is that activities of daily living become difficult to perform
and, if MS progression continues without treatment, even the breathing and cardiac muscles cease to function.

The earlier MS is treated, the more effective the treatment intervention will be (Frohman 2006; Murray 2006). Medication and rehabilitation may attenuate symptoms or slow the disease’s progression. Rehabilitation and medication can have a synergistic effect on the improvement of daily life, thereby potentially returning the patient to pre-relapse function quality of life.

Determining the effectiveness of various therapy strategies, however, requires consistent and constant assessment throughout life. To detect the number and locations of plaques/lesions, two common assessment tools used are magnetic resonance imaging (MRI) and functional MRI (fMRI). However, both MRI tools have limitations for use in assessment. First, it is relatively expensive. Second, MRI findings, while useful in elucidating CNS changes, may not be useful for assessing physical function. Accordingly, Murray (2006) stated that, “In clinical practice, assessing the number and severity of relapses and changes in neurological status are the only practical measures, as findings on magnetic resonance imaging are not well correlated with outcome, especially if a standardized approach is not used.” This inadequacy of being able to translate imaging results to functionality status shows the need for other concurrent measures.

Current clinical assessment tools are not necessarily valid for assessing function, either. Most scales are qualitative, such as the Expanded Disability Status Scale (EDSS) (Gaspari 2002), which was used in this study (Appendix A). For example, the EDSS, one of the most often used tests (nationalmssociety.org 2006) requires the client to walk. The scale measures the distance walked. Thus, such scales may provide very limited or useful diagnostic information about specific physical capabilities due to the reliability of EDSS level caused by variability of the
participant from day to day. The test results could lead to exercise prescriptions that are inappropriate, thereby possibly prolonging recovery.

An assessment battery that requires the client to perform several functional tasks may become the benchmark for physical function evaluation of MS. However, prior to development of such a battery, two processes must be understood: 1) the biomechanics of such tasks and 2) how MS severity affects the movement strategies used to accomplish various tasks.

The sit-to-stand (STS) task refers to a person rising from a seated position. The STS is one such functional task that should be included in a valid functional test of MS motor ability. The STS is involved in everyday life when rising from seated positions in the bathroom, for example, or standing up from chairs in the home or in public, or getting out of vehicles. Furthermore, the task has been classified as the most mechanically demanding task of daily function (Schultz et al. 1992; Lundin et al. 1995; Kerr et al. 1997).

Therefore, the STS movement will be the task used in the current study. By understanding how the disease progression influences the changes of the biomechanics (the movements and forces that produce movement) involved in performing the STS, then a tool to assess performance of this task may be developed.

Understanding the underlying biomechanics may help to provide insight to the controlling factors of movement, therefore, helping clinicians identify current functional ability in order to improve function. Therefore, the questions of interest for this study are: a) What are the adaptive movement strategies used while rising from a chair by participants with MS who have increased compared to decreased ‘disability status’ scores?; and b) “Why is this particular adaptive strategy exhibited (i.e., what muscle groups are being used differently to compensate for weakness of other lower extremity or trunk muscles?)?
Purpose of the Study

Therefore, the purpose of the study is to determine if there are changes in kinematics (joint and segment motions) and electrical activation of muscles with increased stages of MS. The overall expected outcome is that the higher the EDSS classification for an MS participant (i.e., decreased walking ability), the more neurodegenerative properties increase, thus the greater the biomechanical differences will be displayed compared to the participants with lower EDSS scores, that is, less MS involvement and increased walking ability. It is anticipated that MS patients, particularly those with increased MS involvement, will exhibit biomechanical strategies of rising similar to those of other populations with muscle weakness, e.g., older adults (Papa 2000). This is one that uses an increased time duration and momentum build up for compensation of decreases of voluntary muscle control.

Description of the Sit-to-Stand

To better understand the anticipated outcomes, the STS movement will be described. According to Kerr (1997), the general population (GP) strategy of typical adults to perform the STS can be described as a discrete, but continuous movement with two overlapping linear phases, the horizontal and vertical (Kerr 1997). From a sitting position, the horizontal phase begins when head-trunk (HT) segment forward motion begins and ends when peak knee flexion occurs. The vertical phase then begins; it ends when extension of knee and hip joints is completed.

Within the horizontal phase, the HT segment motion occurs due to hip flexion and aided by the arms, coming closer to the center of mass (COM). The arms coming closer to the HT segment aids in the increase of forward angular momentum and rotational speed of HT segment by decreasing the length of the radius of gyration for combined HT and arm segment. The
vertical phase starts by the initiation of knee extensor (KE) activity as the HT segment rotates about the hip joint forward and down, causing an overlapping of the phases. This initiation of KE muscle moves the thigh segment (TH-SEG) relative to shank (SH-SEG), which elevates the proximal portion of the TH-SEG. As the hip joint is raised, the HT segment extends relative to the T segment simultaneously by the hip extensors (HE) and spine erectors (SE).

Predicted Outcomes and Rationales

The MS movement strategy of STS was predicted to be similar to the GP but would more closely approximate that of other populations who cannot generate optimal force. Populations such as the obese (Sibella 2003), elderly (Papa 2000), and other neurological disorder populations (Mak 2003) have used similar strategies to accomplish STS, based on the progression of their disease.

As decreased KE muscle activation and net muscle moments were expected to be generated during this phase by individuals with greater MS involvement, these individuals will need to produce KE muscle activation and joint moments earlier and for a longer time. Therefore, the participants are expected to display increased initial velocities prior to KE muscle activity and decreased extension velocities, to assist in moving the body’s COM forward (and upward).

Also in contrast to the GP strategy, to compensate for weak knee extensor/flexor muscles, it is surmised that the performers would rock the trunk in the antero-posterior (A-P) directions at the start of the horizontal phase to gain horizontal momentum of the HT segment. This momentum contributes to a shift of the body weight forward and moves the center of pressure (COP) to an anterior position relative to the malleolus.
For the vertical phase, it is predicted that it would be initiated earlier, relative to the total STS time, but it would last longer. Further anticipated is a delay in the HE moment time duration. For hip joint moments, HE moments were not expected to be generated until the antero-posterior (A-P) location of the center of force (COF) shifted posterior relative to the A-P location of the lateral malleolus. As the shift in position of the COF occurs, the previously flexed joints of hip and ankle will then begin to extend to have an upright postural position.

**Significance of the Study**

When it is proven that certain biomechanical factors degrade with increased MS levels, as evident by STS results, the STS measures can lead to another assessment to evaluate MS disease progression on motor function. The range of values can lead to another classifying factor when attempting to classify individuals on MS disability functions. With the inclusion of the new value ranges, physical therapists can work on strength gains, based on the increase in muscular recruitment, and in turn retrain the coordination patterns, based on joint velocities seen in less affected MS patients, and in the existing populations that they are familiar in helping.

The performance measures on the STS can disclose physiological factors, such as muscle recruitment differences as MS progresses that are not seen on an exterior evaluation. A clinician and physical therapist will then be able to accurately develop a treatment that addresses the changes involved in controlling the adaptive strategy. The clinician may also see the involvement that the prescription drug dosage creates on muscular function and movement strategies.

Knowing how the MS population accomplishes the movement because of disease progression helps the clinician and physical therapist infer if the significant results are treated effectively with which particular combination of symptomatic prescription drugs, PT and/or temporary prescriptions.
CHAPTER 2

LITERATURE REVIEW

MS Pathology

Multiple Sclerosis (MS) is a disease classified as neurodegenerative affecting the central nervous system (CNS). Although the disease had been observed in Europe since the middle ages, it was not officially classified until 1873 by the medical community. In 1868 Dr. Jean-Martin Charcot noticed a woman who had tremors that he had never seen before; during her autopsy he noticed the lesion/plaque on the brain (nationalmssociety.org 2005).

MS patients have lesions/plaque that form on the axons of the brain and spinal cord impairing the transmission of signals from one neuron to the next. The lesions form around the covering of the axons (myelin sheath) and demyelinate the surrounded area. Plaques also affect the ability of the oligodendrites to effectively repair damaged neurons (Murray 2005).

Because the damage that occurs to the myelin sheaths, axons are impaired and due to the specific areas of damage can involve, any motor or sensory system within the CNS. The number and severity of physical problems also increases with the disease’s progression, the combinations of possible symptoms and problems are as different as the number of people affected.

Related to the motor system, reduced muscle strength and lack of body regulation can cause problems such as (e.g., bladder incontinence, spasticity, gait disorders, limb weakness or fatigue and increased muscle tone). Vision problems, may develop from plaque around the optic
nerve, resulting in hypertonicity (a condition that produces pain with eye motion), vision
decrease or blindness.

The segmental rigid body model was built using a modified version of Pai’s link segment
model (Pai 1991). The STS movement strategy is simplistically viewed as two overlapping linear
phases: horizontal and vertical. As Pai stated, the major contributor to horizontal phase is the
upper body segment and the vertical phase is mainly influenced by the thigh motion (Pai 1991).
These segments are the major contributors to the linear motions of the body during the STS. For
accomplishment of the task, the overlap is required to translate the forward momentum to the
vertical displacement of the center of mass.

After the contributions to linear phases are examined, Yu suggested that the need to look
at angular segment motion is important for therapists (Yu 2000). This is due to the need for
therapists to relate one segment motion to another. In looking at joint contributions to movement
strategy, joint angular motions can show constraints based on CNS (Yu 2000). In addition,
looking at factors that contribute to normative strategy, the change in center of pressure (COP)
should not be ignored. The participant will shift COP from an anterior to a posterior position of
ankle joint to maximize stability (Schultz 1992).

**Adaptive Strategies**

With non-normative populations, controlling strategies will differ. To compensate for the
decrease in impulse of the knee extensor, the overlap in phases will be increased compared to
normative. The new strategy may compensate for weakness in the quadriceps muscles in
controlling the range of motion (Schultz et al. 1992). The forward momentum is balanced by the
impulse generated by the lower limbs (Kerr et al. 1997). Applying the conservation of impulse-
momentum principle, shows the importance needed for the timing of knee extensor. If knee
extensors cannot rapidly contract, then movement must slow to the speed of neuromuscular recruitment. Thus, longer time duration for the entire task.

As shown in normative population, a shift in COP is expected as with a decrease in the build-up rate of joint moments (Schultz 1992). He theorized that in neurological populations, a decrease in hip flexion moment could reflect problems recruiting motor unit activity, and that slower moment build-up rate and hip extensor moment are responsible for the disruptions from normative STS.

To resist the decrease in physical function physical therapy (PT)/ occupational therapy (OT) are used for their success in rehabilitation of the body. PT/OT has reduced recovery time from relapse, contractures, disuse atrophy, decubiti, risk of falls, decreased dependence and regaining mobility (Paper 2004). For the same accomplishments in working with other populations, the therapist needs to be made aware of acute changes from relapse that will take place and may not be shown by classification of EDSS. The therapist can view the measures to have an accurate judgment of the controlling factor changes of motor and functional capabilities that may go as absent changes when EDSS is used alone (Paper 2004). Knowing the deviations between MS individual classification and between general populations on a quantitative assessment will give a better structure for the exercises so that the therapy is used to its potential for improvement of physical functional ability.

**MS Characteristics**

The initial clinical diagnosis is made after two acute attacks separated in time in the CNS. Although the clinical evaluation waits for two acute attacks, laboratory (MRI, Cerebral Spinal Fluid) findings can support MS diagnoses after one characteristic attack. For diagnostic purposes, Shapiro provides descriptions of MS in four distinct characteristics:
**Relapsing-remitting:**
This level of MS is characterized by the patient suffering from two acute attacks that may subside such that full recovery occurs or some neurological signs/symptoms and residual deficits remain. The periods between relapses are characterized by an obvious lack of disease progression. It is thought that about 80% of MS begins in this manner. Over time, however, for some individuals, the disease does advance, such that the person’s MS level moves disease level to the next stage. About 50% of MS patients will become progressive following the relapsing start, after initial diagnosis.

**Secondary Progressive:**
This stage of the disease begins with an initial relapsing-remitting course, followed by progression at a variable rate that also may include occasional relapses and minor remissions. About 10% of MS individuals worsen right from the start when symptoms first appear.

**Primary Progressive:**
The disease shows progression of disability from its onset, without plateaus or remissions or with occasional plateaus and temporary minor improvements. It is more commonly seen in people who develop the disease after 40 years of age. About 5% of MS patients start with a progressive course and disease progression becomes more fluctuating.

**Progressive relapsing:**
This pattern of MS shows progression from the onset but without clear acute relapses that may or may not have some recovery or remissions.
Once diagnosed with MS, the patient is evaluated on the disease progression by a qualified professional on the EDSS throughout their life. This scale was developed by Dr. John Kurtze in 1953 to give clinician’s a common scale to relate the progression of MS on the person’s physical ability (Murray 2005). The ambulatory function measured by EDSS is shown in Appendix A.

The EDSS scale can be linked with descriptors as: Mild $\leq 3.5$ (full ambulatory function, low pyramidal impairment), Moderate $\leq 7.5$ (increased pyramidal impairment, uses aids for ambulatory function) and Severe $\leq 10$ (extreme pyramidal impairment, confined to motorized wheel chair or death as result of diseases).

Although the scale is the most widely used in the world by professionals for evaluating MS, there are some limitations. The scale is an ordinal scale, which leaves out some changes because of relapse, making it not precise enough to discern entire disease progression. In addition to EDSS, another evaluation instrument is available. Nerve response to stimulation and the resultant velocity (nerve conduction test/ evoked potential test) can be used, but it requires expensive equipment. However, these do not involve controlled movements by the patient.

The benefit of a quantitative parameter accompanying EDSS to assess for the level of physical function would make for a more robust evaluation tool. The STS is simple, fast and can be performed at any motion analysis laboratory. The STS can be used to show the patient’s improvements in strength and motor control due to PT/OT or to measure the effectiveness of a drug protocol on functional performance.

The STS was selected as the functional task of interest for this study, as the STS is said to be the most mechanically demanding daily task.
CHAPTER 3

EFFECTS OF LEVEL OF MULTIPLE SCLEROSIS INVOLVEMENT ON

BIOMECHANICS OF SIT-TO-STAND\textsuperscript{1}

\textsuperscript{1} Thompson, R., Arnett, S., Simpson, K., Crowley, H., Baumgartner, T. To be submitted to Clinical Biomechanics
ABSTRACT

The purposes of the study were to describe the mechanics of the sit-to-stand as performed by individuals with multiple sclerosis (MS), and to determine how the level of MS involvement influences movement and muscle activation strategies selected during standing. Eleven participants were divided into three MS involvement groups, based on the Expanded Disability Status Scale: very mild (0.5-3), mild (3.5-4.5), and moderate (5-6); (n = 6, 3, and 2, respectively). Participants performed six trials of the sit-to-stand movement. Group differences for two-dimensional kinematic, ground reaction force and electromyographic variables were determined using the Kruskal-Wallis test (α = 0.05). No statistical differences were detected, likely due to high intra- and inter-individual variation and small sample size. As a group, the MS participants showed common strategies for muscle activation and control of joint extension velocities. The moderate MS group times during phases were comparable to other neurological populations.

INDEX WORDS: Sit-to-Stand, Multiple Sclerosis, Wavelets, Electromyography, Kinematics, Ground Reaction Forces
**INTRODUCTION**

Multiple sclerosis (MS) is an extremely debilitating, but common, medical condition. MS affects approximately 400,000 Americans, with 200 new individuals diagnosed each week (nationalmssociety.org 2005). Individuals are initially diagnosed with MS between the ages of 20 and 50 years (nationalmssociety.org 2003). Hence, MS is the primary neurological disorder affecting young people, particularly women, according to the National Multiple Sclerosis Society (nationalmssociety.org 2003).

MS is a degenerative disease of the central nervous system (CNS). The disease is characterized by lesions/plaque that demyelinate the axons of CNS interneurons within the CNS and motor neurons. Thus, with MS, the transmissions of signals from the demyelinated interneuron axons to the associated motor neurons become disoriented and erratic (Schapiro 2003). Lesions/plaque also cause decreased magnitudes of transmission impulses and conduction velocity of the electrical signal along the affected axons (Schapiro 2003). Without correct excitatory and inhibitory activity of these interneurons modulating motor control of voluntary muscles, voluntary motor control is disrupted, hence, functional impairment results.

The earlier that MS is treated, the more effective the treatment intervention (Frohman 2006; Murray 2006). Medication and rehabilitation may attenuate symptoms and/or slow the disease’s progression. Rehabilitation and medication also can have a synergistic effect on the improvement of carrying out tasks of daily life, thereby potentially returning the patient to pre-relapse function quality of life.

The MS movement strategy of sit-to-stand (STS) was predicted to be similar to the general pattern (GP) but would more closely approximate that of other populations who cannot generate optimal force. Populations such as the obese (Sibella 2003), elderly (Papa 2000), and
other neurological disorder populations (Mak 2003) have used similar strategies that serve to reduce muscle activation by increase joint velocities to accomplish STS based on the progression of their disease.

Understanding the underlying biomechanics may help to provide insight to the controlling factors of movement, therefore, helping rehabilitative clinicians identify current functional ability. Since MS lesions disrupt muscle control, muscular weakness can be an outcome of the disease. What researchers do not know is how this muscular weakness changes the movement strategies to compensate for a muscle that has degraded function due to lesions and what effect this has on the biomechanical factor of movement.

The overall expected outcome is that the higher the Expanded Disability Status Scale (EDSS) classification for an MS participant (i.e., decreased walking ability), the more neurodegenerative properties increase, and, thus, the greater the biomechanical differences will be displayed compared to the participants with lower EDSS scores; that is, less MS involvement and increased walking ability. It is anticipated that MS individuals, particularly those with increased MS involvement, will exhibit biomechanical strategies of rising similar to those of other populations with muscle weakness, e.g., older adults (Papa 2000). These populations use an increased time duration and momentum build-up for compensation of decreases of voluntary muscle control.

What is not known about the MS population is the momentum changes that occur during specific phases of the STS, such as the anterior-posterior (A-P) impulses during rising and stabilizing that can indicate the effect of an increased velocity on the center of mass (COM) and the impulse required to raise the COM vertically from the seated position. Therefore, the purpose
of the study is to determine if there are changes in kinematics (joint and segment motions) and
electrical activation of muscles with increased stages of MS.

**METHODS**

**Design:** Quasi-experimental, non-parametric statistical test among three MS-level groups.

MS volunteers were recruited from the community and via doctor referrals (Appendix A). The volunteers met the following inclusion criteria: 1) 20-80 yrs of age, 2) EDSS score between 0.5 and 6.5, representing low to moderate physical impaired function, and 3) EDSS score being constant for the preceding three months. Participants were: free from any non-MS related ailments; relapse-free for three months; not classified under any other disability classification that could influence performance adversely (e.g., lower extremity amputation or medically obese); free from injuries that could have affected their normal, physical performance; and had not begun using new over the counter (OTC) or prescription drugs within the past three months (Appendix B). The 11 participants were assigned to one of three MS involvement groups based on their EDSS scores: very mild = 0.5 - 3.0, mild = 3.5 - 4.5 and moderate = 5.0 – 6.0 (n = 6, 3, and 2, respectively). There was no participant drop-out during the study. The participant information for each group is shown in Table 1.

Optoelectronic, ground reaction forces (GRF) and electromyographic (EMG) signals were collected via the Peak Motus Motion Measurement System® (v.9.0, Vicon, Inc., Oxford, UK). For kinematic data, a Vicon MX® high-speed C-MOS camera (120 Hz) captured a sagittal plane view of the right side of the participant’s body. To collect GRF of the right foot, a force platform (OR6-6-0, AMTI®, Watertown, MA.) embedded in the floor was used (sampling rate: 1200 Hz, gain: 4000 Hz; low-pass filter: 10.5 Hz)
To collect surface EMG signals using the MYOPAC® system (v. Standard, Run Technologies, Mission Viejo, CA) bipolar, Ag-AgCl disposable electrodes (3.49 cm diam; average inter-electrode distance of 2.3 cm; Biopac Systems, Inc., Goleta, CA) were placed on muscles of the right lower extremity of the vastus lateralis (VL), rectus femoris (RF), biceps femoris (BF) semitendinosus (ST) medial gastrocnemius (MG), and soleus (SOL); the spine erector (SE). The reference ground electrode was attached over the tibial tuberosity (Cram 1998). The EMG signals (sampling rate 1200 Hz; CMRR: 10,000:1) were preprocessed in the conditioner/amplifier worn around the waist, then transmitted to the receiver (MPRD-101 Receiver/Decoder®) and input to the computer via a 16 bit A/D board.

For kinematic data, as shown in Figure 3.1, reflective markers were placed on the right side of the body on the head of the 5th metatarsal, posterior border of the calcaneus, midpoint of the lateral malleoli, lateral tibial condyle, greater trochanter, highest palpable point on the pelvic crest, acromion process, olecranon process and on the participant’s head, slightly superior to the
proximal tip of the pinna.. The camera was 12 m from the participant at a perpendicular to the participant (ht of camera ≈ 1 m from ground). The calibration object of 2 m high and 0.9m wide was used to calibrate the 1.8 m² field of view. The participant’s right foot was placed perpendicular to the camera on the force platform.

Prior to testing, the participant read and signed the Informed Consent (Appendix C), Health Status Questionnaire (Appendix B), and Physical Assessment Questionnaire (Appendix D). Anthropometric measurements were taken (e.g., segment lengths, mass). After measurements were taken, the participant performed the EDSS test, in which they walked a distance until they felt they had to rest. While the participant sat in a natural standing position in the test location (Figure 3.1), the spatial locations of the reflective markers were captured for later use to determine the coordinate system locations of natural standing.

For testing, the participant performed six successful trials of the STS with 1-minute rests between trials. The participant began the trial in a sitting position on a chair, with the arms crossed in front and both knees at a 90° knee angle (measured manually using a goniometer). The left foot was spaced at approximately shoulder width from the right foot. The lower extremities were aligned to the sagittal plane. Next, the participant stood up as naturally as possible, while keeping the arms crossed, and then stood for four seconds. A trial was considered successful if the participant rose to a full standing posture without the right foot touching the ground beyond the force platform border and then remained stationary for four seconds without the researcher physically assisting the performer.

For the kinematic analyses, the scaled spatial coordinates were smoothed using a quintic spline based on Woltering’s GCVSPL. Total STS movement time was considered to be from the instant the hip joint motion began until the instant when maximum hip extension was first
achieved after knee extension was completed. For each lower extremity joint, maximum flexion and extension angles for positions, velocities and accelerations were generated. For each participant the GRF was scaled (sGRF) to the body weight recorded. Calculated from the sGRF signals were time and impulses of the STS for the vertical (V) and A-P channels as well as the maximum value for each channel during the movement. The impulses where calculated by the product of the mean force over the duration of the phase and the time duration of the phase. The phases for the A-P channel were forward impulse starting at frame of hip motion to frame of full hip extension and the impulse to maintain stability from the full hip extension to end of movement. The phase for the V channel was the impulse required to raise the joints to full extension determined from frame of hip motion to frame of full hip extension. The examination of the impulses allowed for change in momentum required to complete the movement.

A wavelet analysis using Daubechies db4 waveform was used to decompose the raw EMG signal into four levels of half-step frequency bands. The first (20-200 HZ) coefficient was used to reconstruct the EMG signal, as this band represent frequencies reported from previous EMG STS article (Ramsey 2004). The participants reconstructed signal of the muscle during the trial was scaled to the mean of the five highest coefficients of that muscle for the particular trial. The average recruitment of the scaled reconstructed signal was used to compare muscle activation among groups. The time of the maximum-scaled reconstructed signal was also determined.

The differences among MS groups were analyzed using Kruskal-Wallis tests (SPSS™, v.11.0, Chicago, IL). Outcomes were significant at p < 0.05.

**RESULTS**
The participant information and statistical comparisons among EDSS groups are shown in Table 3.1. There were no statistical differences among the groups for any participant variables. Appendix E shows a representative sample of kinematics, GRF and EMG of each group.

Table 3.2 contains the statistical results for the kinematic variables. For any of the variables generated from the spatial makers, there were no statistically significant differences among groups. Reviewing the statistical tables demonstrates the coefficient of variance (COV) for each group was larger than was expected with individuals that had been relapse-free for several months. However, a tendency emerged that most participants’ first and second trials were outliers from the rest of their data, indicating an adjustment to the task and environment.

Table 3.3 contains the statistical results for the GRF variables. None of the GRF variables among groups was found to be statistically significant. Again, reviewing the statistical tables shows the COV exceeding 25% in most cases. With some of the GRF variables having high COV, the theory that the EDSS cannot properly categorize individual MS disease progression should be noted.

Table 3.4 contains the statistical results for the analysis of the EMG recordings for among groups. Tendencies in the EMG data do show different times of peak activity for variables among groups. However, this is a tendency, as no recorded muscle activation was found to be statistically different among groups.

**DISCUSSION**

Being able to rise to a stand during daily life enhances independence and reduces the risk of institutionalization (Lundin et al. 1995). Therefore, the purposes of the study were to describe the mechanics of the STS for MS participants and how the mechanics varied among MS individuals based on their level of MS. It was anticipated that individuals with very mild or mild
MS would exhibit kinematic, GRF and EMG characteristics similar to typical adult characteristics, while those individuals with moderate MS would adopt movement technique strategies that would compensate for muscle weakness of involved muscles.

Prior to discussing the results, limitations of the study are noted. As every individual with MS is likely to have unique lesion locations, it is difficult to generalize to all MS individuals the displayed biomechanics due to potentially distinctive neuromuscular effects. Consequently, the sample size was too small to make definitive comparisons among individuals who had different levels of MS. Second, the EDSS, the scale used in this study and very often used to classify MS involvement for research purposes, has limitations as a valid measure of physical function. However there should be some correlation to the distance an MS individual can walk (EDSS measure) with the biomechanics exhibited while rising from a chair several times.

For overall performance, all participants were able to rise without use of arms and then maintain standing for all trials without using external support to help stand or to prevent instability. Therefore, two overview variables reflecting STS ability were the time to rise and time required to become stable upon standing (time to rise and time to stable). It was expected that with increased MS involvement, the times would increase. For the very mild and mild MS individuals, the time to rise values were comparable to typical adult populations (Kerr et al. 1997) the range of values for very mild and mild MS groups were 1.4 -1.6 seconds were Kerr reported times under 2 seconds were typical. Therefore, MS individuals classified as mild or better demonstrated that their ability to accomplish the task was intact.

For the moderate MS group, their times were 2.5 seconds on average, which is comparable to older adult populations (Papa et al. 2000), whose values were similar. Although the moderate MS group was able to complete the task, their mean age was 61 years, whereas the
older adult population ages ranged from 65-81 years. Therefore, although the moderate MS participants are able to accomplish the task, the tendency to take longer to rise and longer to become stable demonstrates that function is compromised as the EDSS predicts. To better measure physical function, for the STS task, it may be possible to use the rise time as a simple measure, particularly if no other visibly obvious movement abnormalities are present.

Qualitatively, it was apparent that individuals varied in their rising strategy. For vertical GRFs, there was a tendency for the peak V force to be decrease as time increased. This is supported by impulse momentum principle (force x time = change momentum) during the vertical phase of the movement. The moderate MS groups used a longer time needing decreased peak V force to achieve the same change in momentum as very Mild and Mild group, who took a shorter time but a greater peak V force.

Reviewing the kinematics, velocities of the joints supports the idea of a common MS strategy to accomplish the STS. The participant’s joint extension velocities for a single joint were similar to all lower extremity joints throughout the trial.

The MS groups’ time of peak muscle activity exhibited tendency for a similar sequential order. The pattern started with the SE, then the VL and RF, then the BF and ST, and lastly, the SOL and MGAS. This pattern is consistent with Doorenborsch’s findings (Doorenborsch et al. 1994) for peak EMG activity in relative to STS cycle. This may show that as MS progresses, neuromuscular recruitment is not as degraded as previously thought and that muscle activation patterns do not degrade as MS progresses.

**CONCLUSION**

In conclusion, MS participants diagnosed as having very mild to moderate MS involvement on the EDSS scale exhibited a similar kinematic strategy and EMG activation to
stand from a seated position. Limitations of the study came from small sample size and participant MS group classification. An accurate classification could be made if a more measurement-based battery of test was given to the participant. The EDSS, mainly focusing on a single walking bout, was a major limitation as participants remarked that performance changed daily, depending on environmental factors, such as heat.

EMG data analysis expectation was that wavelet analysis with different filter windows would allow for more detailed frequency analysis, leading toward classifying participants under certain muscular recruitment patterns. However, upon review of the frequency band that followed previous frequencies seen in the STS (Ramsey 2004) no statistical difference was shown among the MS groups.

It had been predicted that impulse analysis during the rising and stabilizing phases would give a better dissection of the momentum changes as the participant performed the movement. No statistical difference in time or peak V and A-P channels indicates a difference in impulse was not needed, as phases were consistent across all groups.

RECOMMENDATIONS

Further research with different frequency bands and higher levels of down sampling decomposition are needed to derive more precise frequency bands to better analyze impaired populations during signal processing. Although not statistically different, there qualitatively appears to be a need for postural sway training as the levels of MS increase.

Also recommended are possible strength measures assessed of the upper or lower body, depending on the nature of the task, as to help classify individuals on MS disease progression. For better classification, having the participants classified based on the MS characteristics may allow for a better grouping strategy.
REFERENCES


nationalmssociety.org, 2005.


### Table 3.1

Participant Characteristics [mean (SD)] of MS Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Very Mild (n=6)</th>
<th>Mild (n = 3)</th>
<th>Moderate (n = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>47 (10.6)</td>
<td>53.6 (20.6)</td>
<td>61.5 (9.1)</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>64.7 (6.1)</td>
<td>76.8 (17.7)</td>
<td>59.75 (3.6)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.2(6.8)</td>
<td>166.2(5.5)</td>
<td>163.2 (3.9)</td>
</tr>
<tr>
<td>EDSS</td>
<td>2.25 (0.7)</td>
<td>4.5 (0.0)</td>
<td>5.5 (0.7)</td>
</tr>
</tbody>
</table>

### Table 3.2

Kinematic Outcomes. No statistical significances were detected among MS groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>mean (SD)</th>
<th>COV</th>
<th>K-W</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip Max (deg)</td>
<td>29.4 (36.1)</td>
<td>122.6</td>
<td>1.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Hip Min (deg)</td>
<td>-33.4 (71.4)</td>
<td>-213.2</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Knee Max (deg)</td>
<td>22.9 (56.4)</td>
<td>245.7</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Knee Min (deg)</td>
<td>-50.4 (59.8)</td>
<td>-118.7</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Shoulder Max (deg)</td>
<td>15.0 (22.1)</td>
<td>147.9</td>
<td>4.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Shoulder Min (deg)</td>
<td>-9.2 (22.9)</td>
<td>-247.0</td>
<td>4.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Hip Max (deg s-1)</td>
<td>95.8 (33.7)</td>
<td>35.2</td>
<td>1.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Hip Min (deg s-1)</td>
<td>-99.1 (44.7)</td>
<td>-45.1</td>
<td>4.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Knee Max (deg s-1)</td>
<td>96.2 (34.7)</td>
<td>36.1</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>Knee Min (deg s-1)</td>
<td>-60.9 (71.1)</td>
<td>-116.8</td>
<td>1.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Shoulder Max (deg s-1)</td>
<td>51.0 (21.8)</td>
<td>42.7</td>
<td>2.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Shoulder Min (deg s-1)</td>
<td>-45.4 (24.7)</td>
<td>-54.4</td>
<td>4.6</td>
<td>0.1</td>
</tr>
<tr>
<td>Hip Max (deg s-2)</td>
<td>1270.0 (973.0)</td>
<td>76.6</td>
<td>1.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Hip Min (deg s-2)</td>
<td>-1086.8 (1167.2)</td>
<td>-107.4</td>
<td>1.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Knee Max (deg s-2)</td>
<td>456.8 (318.8)</td>
<td>69.8</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Knee Min (deg s-2)</td>
<td>-490.2 (376.3)</td>
<td>-76.8</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Shoulder Max (deg s-2)</td>
<td>411.5 (407.21)</td>
<td>217.5</td>
<td>2.9</td>
<td>0.2</td>
</tr>
<tr>
<td>Shoulder Min (deg s-2)</td>
<td>-538.8 (269.5)</td>
<td>-50.0</td>
<td>2.9</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Note: K-W= Kruskal Wallis test
Table 3.3
GRF Outcomes. No statistical significances were detected among MS groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>mean(SD)</th>
<th>COV</th>
<th>K-W</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-P forward impulse (N s)</td>
<td>0.06(0.08)</td>
<td>123.5876</td>
<td>0.378</td>
<td>0.82746</td>
</tr>
<tr>
<td>A-P forward Stable Impulse (N s)</td>
<td>-0.33(0.12)</td>
<td>36.90449</td>
<td>3.409091</td>
<td>0.181855</td>
</tr>
<tr>
<td>Vertical Raise Impulse (N s)</td>
<td>1.09(0.78)</td>
<td>71.99372</td>
<td>0.181818</td>
<td>0.913101</td>
</tr>
<tr>
<td>Time to Raise (s)</td>
<td>1.57(0.80)</td>
<td>51.4423</td>
<td>2.80303</td>
<td>0.246224</td>
</tr>
<tr>
<td>Time to Stable (s)</td>
<td>1.76(0.49)</td>
<td>27.9745</td>
<td>3.712121</td>
<td>0.156287</td>
</tr>
<tr>
<td>Total Time (s)</td>
<td>3.35(0.56)</td>
<td>16.74877</td>
<td>2.181818</td>
<td>0.335911</td>
</tr>
<tr>
<td>Max Vertical (N BW-1)</td>
<td>2.03(0.13)</td>
<td>6.669102</td>
<td>0.909091</td>
<td>0.634736</td>
</tr>
<tr>
<td>Max A-P (N BW-1)</td>
<td>0.21(0.05)</td>
<td>25.77131</td>
<td>2.848485</td>
<td>0.240691</td>
</tr>
</tbody>
</table>

Note: K-W = Kruskal Wallis test

Table 3.4
EMG Outcomes. No statistical significances were detected among MS groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>mean(SD)</th>
<th>COV</th>
<th>K-W</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL</td>
<td>7.8 (1.2)</td>
<td>16.29</td>
<td>1.3</td>
<td>0.5</td>
</tr>
<tr>
<td>RF</td>
<td>6.6 (0.9)</td>
<td>13.8</td>
<td>2.3</td>
<td>0.3</td>
</tr>
<tr>
<td>BF</td>
<td>8.8 (1.8)</td>
<td>21.1</td>
<td>2.1</td>
<td>0.3</td>
</tr>
<tr>
<td>SM</td>
<td>7.5 (1.0)</td>
<td>13.7</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>SOl</td>
<td>7.6 (1.9)</td>
<td>24.9</td>
<td>0.0</td>
<td>0.7</td>
</tr>
<tr>
<td>MGAS</td>
<td>6.1 (1.2)</td>
<td>21.0</td>
<td>4.4</td>
<td>0.1</td>
</tr>
<tr>
<td>SE</td>
<td>8.2 (1.3)</td>
<td>16.0</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>VL time of max. coefficient (s)</td>
<td>2.3 (0.3)</td>
<td>17.0</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>RF time of max. coefficient (s)</td>
<td>2.3 (0.4)</td>
<td>18.9</td>
<td>2.7</td>
<td>0.2</td>
</tr>
<tr>
<td>BF time of max. coefficient (s)</td>
<td>2.5 (0.3)</td>
<td>14.8</td>
<td>2.1</td>
<td>0.3</td>
</tr>
<tr>
<td>SM time of max. coefficient (s)</td>
<td>2.5 (0.5)</td>
<td>20.9</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>SOl time of max. coefficient (s)</td>
<td>2.6 (0.4)</td>
<td>17.2</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>MGAS time of max. coefficient (s)</td>
<td>2.5 (0.3)</td>
<td>15.1</td>
<td>2.4</td>
<td>0.2</td>
</tr>
<tr>
<td>SE time of max. coefficient (s)</td>
<td>2.2 (0.3)</td>
<td>16.6</td>
<td>0.2</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Note: K-W = Kruskal Wallis test

*CPMCM : Coefficient Percentage of Mean Maximum Coefficients*
ACKNOWLEDGEMENTS

I wish to thank Jae Pom Yom, Petur Sigurdsson, Yang-Chieh Fu, Tom Dipiro and Dr. Ming Lai for their assistance in conducting this study. I would also wish to thank the Athens Chapter of the National MS Society for their participation and enthusiasm.
APPENDICIES

APPENDIX A

Doctor Office Fax

The study of “Biomechanical analysis of the sit-to stand in patients with varying levels of MS” is being conducted at the University of Georgia.

The task is for the participant to rise from the seated position and maintain an upright posture for a brief period of time. During the task they will have measurements taken using motion analysis system and EMG recordings.

The purpose of the study is to determine the difference in joint motions and moments associated with sit-to-stand strategy along the stages of MS.

Your help in recruiting patients to volunteer for this study will be the cornerstone for success. With your help, your MS patients can further their recovery from relapses. The data collected can lead to better evaluation of MS disease progression on motor function. With relatable variables physical therapist can retrain the coordination patterns based on joint motions and work on power gains based on the moments and rate to peak forces observed in comparison to the existing populations that they are familiar in helping.

For any questions or concerns please contact Dr. Kathy J. Simpson at 706-542-4385 or ksimpson@uga.edu and Ryan Thompson at 706-542-4132 or rthomps1@uga.edu.
APPENDIX B

MS Health Status Questionnaire

Please respond as completely as possible. Your responses to this questionnaire will be kept confidential and will only be reviewed by the two main investigators.

_____ Male _____ Female  Age _______

________Height (cm)  ________Weight (kg)

What is your current rating on the EDSS? __________

How long have you been diagnosed with Multiple Sclerosis? ______ Yr

How long have you been taking your current medication(s)? ________ Yr

Are you currently having any problems because of relapse with Multiple Sclerosis?

Circle:   Yes     No  If yes, explain the problem briefly:

______________________________________________________________________________

______________________________________________________________________________

Health Condition

1. Please identify how you would evaluate your health overall (circle best choice below)

   Excellent  Good  Fair  Somewhat poor  Very poor

Do you have any current medical problems?  Circle:     yes  no    If yes, complete the following. Use one row for each medical problem.

<table>
<thead>
<tr>
<th>Describe the problem</th>
<th>Has it been diagnosed by a physician? (yes/no)</th>
<th>Treated by a physician or other medical professional? (yes/no)</th>
<th>Does the problem affect your balance, strength, vision, movements; or produce nausea or dizziness? (yes/no)</th>
<th>Are you currently taking medication for problem? (yes/no). If yes, list the medication.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Have you started taking a new medication within the last three months or changed the dosages of any other medications (prescription or nonprescription) you currently take that have any of the following side effects? (Circle Yes or No)

a. Balance problems? Yes / No
b. Feel sick or nauseated during physical activity? Yes / No
c. Dizziness? Yes / No
d. Vision problems? Yes / No
e. Feel coordination is off? Yes / No
f. Ability to think or follow directions Yes / No
g. Other side effects: Yes / No If yes, describe side effect:
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Have you ever experienced the following? Place a checkmark under “yes” or “no.” If yes, then check off the appropriate spaces.

Yes No Broken bone? If so: ____ right leg ____ left leg ____ spine ____
Yes No Surgery? If so: ____ right leg ____ left leg ____ spine ____
Yes No Sprain to the following: right or left hip ______ right or left knee ______
Yes No Are you currently experiencing any pain/discomfort/injury? If yes, describe:
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Yes No Are you currently recovering from an illness or an injury? If yes, or not sure, describe:
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Yes No Is there any other information related to your health that we should know? If yes, explain.
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Other comments:
APPENDIX C

Informed Consent for Research Participation

INFORMED CONSENT FOR RESEARCH PARTICIPATION

I, ______________ agree to participate in the research study entitled, “Biomechanical analysis of sit-to-stand in patients with varying levels of MS”, which is being conducted by Dr. Kathy Simpson (706/542-4385) and Mr. Ryan Thompson (graduate student, 706/542-4132), Department of Kinesiology at the University of Georgia, Athens, GA. I understand that this participation is voluntary; I can withdraw my consent at any time without penalty and have the results of the participation, to the extent that it can be identified as mine, be returned to me, removed from the research records, and destroyed.

The objective of this research is to investigate the comparative movement strategies and muscular activity associated with ratings of MS patients on the EDSS compared to Non-MS Patients.

I may benefit by developing information related to my functional ability that I and my physical therapist/ physician can use to adjust therapy intensities or workloads.

My part in this study will last for approximately 1 day.

The procedures are as follows: First, my eligibility to participate will be determined. To do this, I, the potential participant, will obtain medical clearance and validation of EDSS rating from my physician or neurologist to participate in this study. Next, I will sign this informed consent form after having the procedures explained to me. Then I will be given a confidential questionnaire regarding my current health status, relevant health history and my physical activity I perform. At this time, I will be told that I am eligible/ineligible to participate in the study.

Second, I will come to the UGA Biomechanics Laboratory of the Department of Kinesiology (Rm 103, Ramsey Building, Academic Wing, UGA) to be tested. Certain measurements of my body dimensions, e.g., height, weight, leg length, etc. will be made. Electrodes for electromyography (measurement of electrical activity produced by my muscles in a process similar to measuring brain waves using EEG) and reflective markers for tracking my movements by a special digital camera will be attached to the skin of the right side of my body. The electrical activity of my muscles at rest will be measured, and then the locations of the reflective markers filmed while I am standing. Next, I will undergo a warm-up consisting of walking around the laboratory until comfort level for sufficient warm up is achieved. After practicing the task of standing several times, I will then stand up from a chair from a seated position as naturally as possible, then stand still for four seconds. I will perform 10 – 15 trials of standing up.

During each standing performance, the electrical activity signals of my muscles will be collected, the positions of the reflective markers will be filmed, and the forces that I push against the floor with my right foot will be measured using a force platform that I will stand on. A side view of your performances also will be videotaped for later observational purposes only. The testing will take about two hours to complete.
Discomfort or muscle soreness in the legs may occur for a few days after participation, as can occur due to participating in any physical activity. However, performance of this task is no more demanding on the body than if I stand from seated position, and the number of performances is considerably less than the number of times people typically stand up during the course of a day. Therefore, the probability of soreness or discomfort is extremely small. In addition, if needed, a researcher will stand nearby during your testing to assist you if you need assistance standing or with maintaining balance.

The only people who will know that I am a research participant are members of the research team and the medical personnel who provided my medical clearance for participation. No identifying information about me or provided by me during the research will be shared with others, except if necessary to protect my rights or welfare (for example, if I am injured and need emergency care); or if required by law. As the video data and other data are directly input into the laboratory computer, these data will be confidential and identifiable only by a participant number that is known only to the researchers. I am welcome to view my performances upon completion of the tasks. All data will remain in a secured area. The video files will be destroyed no later than by 01/1/2010 years after the testing date.

For any further questions about the research please contact: Primary Investigator, Ryan Thompson at 706-542-4132 or rthomps1@uga.edu or Co-Investigator, Dr. Kathy Simpson at 706-542-4385 (ksimson@uga.edu). I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Please sign both copies of this form. Keep one and return the other to the investigator.

__________________________________________                     ______/______/______
Signature of Participant                                                                     Date

__________________________________________                     _____/_____/
Signature of Researcher(s)      Date

Dr. Kathy J. Simpson  706/542-4385           ksimpson@uga.edu
Ryan Thompson 706/542-4132               rthomps1@uga.edu

Additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu
APPENDIX D

Participant #: _____
Date: _____

Physical Activity Questionnaire

<table>
<thead>
<tr>
<th>Activity</th>
<th>Total Yrs you’ve engaged in this activity during your life</th>
<th>How often do you now engage in this activity?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 = rarely; 2 = 5-10 times/yr; 3 = 2-3 times/mo.; 4 = 2-3 times/wk; 5 = 4 or more times/wk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What is the length of time (in minutes) you spend each time you engage in this activity?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How would you perceive your level of physical exertion during this activity?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = very low effort, 2 = moderate effort, 3 = fairly effortful, 4 = extremely effortful</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Skill level: If the activity is a sport, rank your highest level of skill attained:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA = not applicable, 1 = never have competed, 2 = recreational competition, 3 = high school competition, 4 = college competition, 5 = greater skill than college level</td>
</tr>
</tbody>
</table>

Baseball
Basketball
Bicycling
Bowling
Dance
Équestrian
Fitness class (ex.: aerobics, step)
Gardening
Golf
Housework
Racquetball (and/or squash)
Running
Swimming
Tennis
Walking
Weight Lifting
Yard work
<table>
<thead>
<tr>
<th>Others: list below</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E

Figure E1. Representative Joint Angles for All MS groups.
Figure E2. Representative Joint Velocities for All MS groups.
Figure E3. Representative Joint Acceleration for All MS groups.
Figure E4. Representative GRF for All MS groups.
Figure E5. Representative EMG for All MS groups.
CHAPTER 4

SUMMARY/CONCLUSION AND RECOMMENDATIONS

Being able to rise to a stand during daily life enhances independence and reduces the risk of institutionalization (Lundin et al. 1995). Therefore, the purposes of the study were to describe the mechanics of the STS for MS participants and how the mechanics varied among MS individuals based on their level of MS. It was anticipated that individuals with very mild or mild MS would exhibit kinematic, GRF and EMG characteristics similar to typical adult characteristics, while those individuals with moderate MS would adopt movement technique strategies that would compensate for muscle weakness of involved muscles.

Prior to discussing the results, limitations of the study are noted. As every individual with MS is likely to have unique lesion locations, it is difficult to generalize to all MS individuals the displayed biomechanics due to potentially distinctive neuromuscular effects. Consequently, the sample size was too small to make definitive comparisons among individuals who had different levels of MS. Second, the EDSS, the scale used in this study and very often used to classify MS involvement for research purposes, has limitations as a valid measure of physical function. However there should be some correlation to the distance an MS individual can walk (EDSS measure) with the biomechanics exhibited while rising from a chair several times.

For overall performance, all participants were able to rise without use of arms and then maintain standing for all trials without using external support to help stand or to prevent instability. Therefore, two overview variables reflecting STS ability were the time to rise and
time required to become stable upon standing (time to rise and time to stable). It was expected that with increased MS involvement, the times would increase. For the very mild and mild MS individuals, the time to rise values were comparable to typical adult populations (Kerr et al. 1997) the range of values for very mild and mild MS groups were 1.4 - 1.6 seconds were Kerr reported times under 2 seconds were typical. Therefore, MS individuals classified as mild or better demonstrated that their ability to accomplish the task was intact.

For moderate MS group, their times were 2.5 seconds on average, which is comparable to older adult populations (Papa et al. 2000), whose values were similar. Although the moderate MS group was able to complete the task, their mean age was 61 years, whereas the older adult population ages ranged from 65-81 years. Therefore, although the moderate MS participants are able to accomplish the task, the tendency to take longer to rise and longer to become stable demonstrates that function is compromised as the EDSS predicts. To better measure physical function, for the STS task, it may be possible to use the rise time as a simple measure, particularly if no other visibly obvious movement abnormalities are present.

Qualitatively, it was apparent that individuals varied in their rising strategy. For vertical GRFs, there was a tendency for the peak V force to be decrease as time increased. This is supported by impulse momentum principle (force x time = change momentum) during the vertical phase of the movement. The moderate MS groups used a longer time needing decreased peak V force to achieve the same change in momentum as very Mild and Mild group, who took a shorter time but a greater peak V force.

Reviewing the kinematics, velocities of the joints supports the idea of a common MS strategy to accomplish the STS. The participant’s joint extension velocities for a single joint were similar to all lower extremity joints throughout the trial.
The MS groups’ time of peak muscle activity exhibited tendency for a similar sequential order. The pattern started with the SE then the VL and RF, then the BF and ST and lastly the SOL and MGAS. This pattern is consistent with Doorenborsch’s findings (Doorenborsch et al. 1994) for peak EMG activity in relative to STS cycle. This may show that as MS progresses neuromuscular recruitment is not as degraded as previously thought and that muscle activation patterns do not degrade as MS progresses.

CONCLUSION

In conclusion, MS participants diagnosed as having very mild to moderate MS involvement on the EDSS scale exhibited a similar kinematic strategy and EMG activation to stand from a seated position. Limitations of the study came from small sample size and participant MS group classification. An accurate classification could be made if a more measurement-based battery of test was given to the participant. The EDSS, mainly focusing on a single walking bout, was a major limitation as participants remarked that performance changed daily, depending on environmental factors, such as heat.

EMG data analysis expectation was that wavelet analysis with different filter windows would allow for more detailed frequency analysis, leading toward classifying participants under certain muscular recruitment patterns. However, upon review of the frequency band that followed previous frequencies seen in the STS (Ramsey 2004) no statistical difference was shown among the MS groups.

It had been predicted that impulse analysis during the rising and stabilizing phases would give a better dissection of the momentum changes as the participant performed the movement. No statistical difference in time or peak V and A-P channels indicates a difference in impulse was not needed, as phases were consistent across all groups.
**RECOMMENDATIONS**

Further research with different frequency bands and higher levels of down sampling decomposition are needed to derive more precise frequency bands to better analyze impaired populations during signal processing. Although not statistically different, there qualitatively appears to be a need for postural sway training as the levels of MS increase.

Also recommended are possible strength measures assessed of the upper or lower body, depending on the nature of the task, as to help classify individuals on MS disease progression. For better classification, having the participants classified based on the MS characteristics may allow for a better grouping strategy.
REFERENCES


nationalmssociety.org (2005).


EDSS Scale.

(Gaspari 2002)

0 : Normal neurological examination (all grade 0 in functional systems)
1.0: No disability and minimal signs in functional systems
1.5 : No disability; minimal signs in more than one functional system
2.0 : Minimal disability in one functional system
2.5 : Minimal disability in two functional systems
3.0 : Moderate disability in one functional system or mild disability in three or four functional systems though fully ambulatory
3.5 : Fully ambulatory but with moderate disability in one functional system, and one or two functional systems grade 2; or two functional systems grade 3; or five functional systems grade 2 (others are 0 or 1)
4.0 : Fully ambulatory without aid; self-sufficient and able to be up and about 12 hours a day, despite relatively severe disability consisting of one functional system grade 4 (others are 0 and 1) or combinations of lesser grades exceeding limits of previous steps; able to walk 500 meters without aid or rest
4.5 : Fully ambulatory without aid; up and about much of the day; able to work a full day; may otherwise have some limitation of full activity or require minimal assistance; characterized by relatively severe disability usually consisting of one functional system grade 4 (others are 0 and 1) or combinations of lesser grades exceeding limits of previous steps; able to walk 300 meters without rest or aid
5.0 : Disability is severe enough to preclude full daily activities, including working a full day; ambulatory without aid or rest for about 200 meters; usual functional system equivalents - one grade 5 alone (others are 0 or 1) or a combination of lesser grades, usually exceeding those for step 4.0
5.5 : Ambulatory for about 100 meters without aid or rest; disability severe enough to preclude full daily activities; usual functional system equivalents - one grade 5 alone (others are 0 or 1) or a combination of lesser grades, usually exceeding those for step 4.0
6.0 : Intermittent or unilateral constant assistance for walking about 100 meters, with or without resting; usual functional system equivalents - combinations with more than two functional systems grade 3+
6.5 : Constant bilateral assistance required to walk about 20 meters without resting; usual functional systems equivalent - combinations with more than two functional systems grade 3+
7.0 : Unable to walk beyond approximately 5 meters, even with aid; essentially restricted to a wheelchair; wheels self in standard wheelchair and transfers alone; up
and about in wheelchair 12 hours a day; usual functional system equivalents are combinations with more than one functional system grade 4+; very rarely, pyramidal grade 5 alone
7.5 : Unable to take more than a few steps; restricted to wheelchair; may need aid in transfer, wheels self but cannot stay in standard wheelchair a full day; may require motorized wheelchair; usually functional system equivalents are combinations with more than one functional system grade 4+
8.0 : Essentially restricted to bed or a chair or perambulated in wheelchair but may be out of bed much of the day; retains many self-care functions and has effective use of the arms; usual functional system equivalents are combinations, generally grade 4+ in several systems
8.5 : Essentially restricted to bed much of the day; retains some self-care functions; has some effective use of arms; usual functional system equivalents are combinations, generally grade 4+ in several systems
9.0 : Helpless and bedridden; can communicate and eat; usual functional system equivalents are combinations, most grade 4+
9.5 : Totally helpless and bedridden, unable to communicate effectively or eat/swallow; usual functional system equivalents are combinations, almost all grade 4+
10.0: Death due to MS results from respiratory paralysis, coma of uncertain origin, or following repeated epileptic seizures.
APPENDIX B

Informed Consent

INFORMED CONSENT FOR RESEARCH PARTICIPATION
I, __________________ agree to participate in the research study entitled, “Biomechanical analysis of sit-to-stand in patients with varying levels of MS”, which is being conducted by Dr. Kathy Simpson (706/542-4385) and Mr. Ryan Thompson (graduate student, 706/542-4132), Department of Kinesiology at the University of Georgia, Athens, GA. I understand that this participation is entirely voluntary; I can withdraw my consent at any time without penalty and have the results of the participation, to the extent that it can be identified as mine, be returned to me, removed from the research records, and destroyed.

The objective of this research is to investigate the comparative movement strategies and muscular activity associated with ratings of MS patients on the EDSS compared to Non-MS Patients.

I may benefit by developing information related to my functional ability that I and my physical therapist/physician can use to adjust therapy intensities or workloads.

My part in this study will last for approximately 1 day.

The procedures are as follows: First, my eligibility to participate will be determined. To do this, I, the potential participant, will obtain medical clearance and validation of EDSS rating from my physician or neurologist to participate in this study. Next, I will sign this informed consent form after having the procedures explained to me. Then I will be given a confidential questionnaire regarding my current health status, relevant health history and my physical activity I perform. At this time, I will be told that I am eligible/ineligible to participate in the study.

Second, I will come to the UGA Biomechanics Laboratory of the Department of Kinesiology (Rm 103, Ramsey Building, Academic Wing, UGA) to be tested. Certain measurements of my body dimensions, e.g., height, weight, leg length, etc. will be made. Electrodes for electromyography (measurement of electrical activity produced by my muscles in a process similar to measuring brain waves using EEG) and reflective markers for tracking my movements by a special digital camera will be attached to the skin of the right side of my body. The electrical activity of my muscles at rest will be measured, and then the locations of the reflective markers filmed while I am standing. Next, I will undergo a warm-up consisting of walking around the laboratory until comfort level for sufficient warm up is achieved. After practicing the task of standing several times, I will then stand up from a chair from a seated position as naturally as possible, then stand still for four seconds. I will perform 10 – 15 trials of standing up.

During each standing performance, the electrical activity signals of my muscles will be collected, the positions of the reflective markers will be filmed, and the forces that I push against the floor with my right foot will be measured using a force platform that I will stand on. A side view of
your performances also will be videotaped for later observational purposes only. The testing will take about two hours to complete.

Discomfort or muscle soreness in the legs may occur for a few days after participation, as can occur due to participating in any physical activity. However, performance of this task is no more demanding on the body than if I stand from seated position, and the number of performances is considerably less than the number of times people typically stand up during the course of a day. Therefore, the probability of soreness or discomfort is extremely small. In addition, if needed, a researcher will stand nearby during your testing to assist you if you need assistance standing or with maintaining balance.

The only people who will know that I am a research participant are members of the research team and the medical personnel who provided my medical clearance for participation. No identifying information about me or provided by me during the research will be shared with others, except if necessary to protect my rights or welfare (for example, if I am injured and need emergency care); or if required by law. As the video data and other data are directly input into the laboratory computer, these data will be confidential and identifiable only by a participant number that is known only to the researchers. I am welcome to view my performances upon completion of the tasks. All data will remain in a secured area. The video files will be destroyed no later than by 01/1/2010 years after the testing date.

For any further questions about the research please contact: Primary Investigator, Ryan Thompson at 706-542-4132 or rthomps1@uga.edu or Co-Investigator, Dr. Kathy Simpson at 706-542-4385 (ksimpson@uga.edu). I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Please sign both copies of this form. Keep one and return the other to the investigator.

__________________________________________                     ______/______/______
Signature of Participant                                                                     Date

__________________________________________                     ______/______/______
Signature of Researcher(s)      Date

Dr. Kathy J. Simpson  706/542-4385       ksimpson@uga.edu
Ryan Thompson        706/542-4132        rthomps1@uga.edu

Additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu
APPENDIX C

MS Health Status Questionnaire

Please respond as completely as possible. Your responses to this questionnaire will be kept confidential and will only be reviewed by the 2 main investigators.

____ Male ____ Female Age _______

________Height (cm) ________Weight (kg)

What is your current rating on the EDSS? __________

How long have you been diagnosed with Multiple Sclerosis? ______ Yr

How long have you been taking your current medication(s)? _______ Yr

Are you currently having any problems as a result of relapse with Multiple Sclerosis?

Circle:   Yes     No  If yes, explain the problem briefly:

______________________________________________________________________________

______________________________

Health Condition

2. Please identify how you would evaluate your health overall (circle best choice below)

Excellent            Good            Fair            Somewhat poor             Very poor

Do you have any current medical problems?   Circle:     yes  no    If yes, complete the following. Use one row for each medical problem.

<table>
<thead>
<tr>
<th>Describe the problem</th>
<th>Has it been diagnosed by a physician? (yes/no)</th>
<th>Treated by a physician or other medical professional? (yes/no)</th>
<th>Does the problem affect your balance, strength, vision, movements; or produce nausea or dizziness? (yes/no)</th>
<th>Are you currently taking medication for problem? (yes/no). If yes, list the medication.</th>
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<tbody>
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<td>3.</td>
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</table>
Have you started taking a new medication within the last three months or changed the dosages of any other medications (prescription or nonprescription) you currently take that have any of the following side effects? (Circle Yes or No)

a. Balance problems? Yes / No
b. Feel sick or nauseated during physical activity? Yes / No
c. Dizziness? Yes / No
d. Vision problems? Yes / No
e. Feel coordination is off? Yes / No
f. Ability to think or follow directions Yes / No
g. Other side effects: Yes / No If yes, describe side effect:
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Have you ever experienced the following? Place a checkmark under “yes” or “no.” If yes, then check off the appropriate spaces.

Yes  No  Broken bone? If so:  ____ right leg  ____ left leg  ____ spine  ____
Yes  No  Surgery? If so:  ____ right leg  ____ left leg  ____ spine  ____
Yes  No  Sprain to the following: right or left hip ______ right or left knee ______
Yes  No  Are you currently experiencing any pain/discomfort/injury? If yes, describe:
______________________________________________________________________________
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Yes  No  Are you currently recovering from an illness or an injury? If yes, or not sure, describe:
______________________________________________________________________________
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Yes  No  Is there any other information related to your health that we should know? If yes, explain.
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Other comments:
APPENDIX D

Participant #: _____
Date: _____

**Physical Activity Questionnaire**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Total Yrs you’ve engaged in this activity during your life</th>
<th>How often do you now engage in this activity?</th>
<th>What is the length of time (in minutes) you spend each time you engage in this activity?</th>
<th>How would you perceive your level of physical exertion during this activity?</th>
<th>Skill level: If the activity is a sport, rank your highest level of skill attained:</th>
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</thead>
<tbody>
<tr>
<td>Baseball</td>
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<td>1 = rarely; 2 = 5-10 times/yr 3 = 2-3 times/mo. 4 = 2-3 times/wk 5 = 4 or more times/wk</td>
<td>1 = very low effort, 2 = moderate effort, 3 = fairly effortful; 4 = extremely effortful</td>
<td></td>
<td>NA = not applicable 1 = never have competed; 2 = recreational competition; 3 = high school competition; 4 = college competition; 5 = greater skill than college level</td>
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<tr>
<td>Basketball</td>
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<td>Bicycling</td>
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<td>Bowling</td>
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<td>Dance</td>
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<td>Equestrian</td>
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<td>Fitness class</td>
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<td>(ex.: aerobics, step)</td>
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<td>Gardening</td>
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<td>Golf</td>
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<td>Housework</td>
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<td>Racquetball</td>
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<td>(and/or squash)</td>
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<td>Running</td>
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<td>Swimming</td>
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<td>Tennis</td>
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<td>Walking</td>
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<td>Weight Lifting</td>
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<td>Yard work</td>
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<td>Others: list below</td>
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APPENDIX E

Participant Fax Release

I, _________________, verify that________________ has been diagnosed with Multiple Sclerosis on _______. The patient has been at their current Expanded Disability Status Scale rating of _______ for _______ months. Further I release said person to participate in the research project.

This information will only be used for the research study of “Biomechanical analysis of the sit-to-stand in patients with varying levels of MS” at the University of Georgia.

For any questions or concerns please contact Dr. Kathy J. Simpson at 706-542-4385 or ksimpson@uga.edu and Ryan Thompson at 706-542-4132 or rthomps1@uga.edu.
APPENDIX F

**Doctor Office Fax**

The study of “Biomechanical analysis of the sit-to stand in patients with varying levels of MS” is being conducted at the University of Georgia.

The task is for the participant to rise from the seated position and maintain an upright posture for a brief period of time. During the task they will have measurements taken using motion analysis system and EMG recordings.

The purpose of the study is to determine the difference in joint motions and moments associated with sit-to-stand strategy along the stages of MS.

Your help in recruiting patients to volunteer for this study will be the cornerstone for success. With your help, your MS patients can further their recovery from relapses. The data collected can lead to better evaluation of MS disease progression on motor function. With relatable variables physical therapist can retrain the coordination patterns based on joint motions and work on power gains based on the moments and rate to peak forces observed in comparison to the existing populations that they are familiar in helping.

For any questions or concerns please contact Dr. Kathy J. Simpson at 706-542-4385 or ksimpson@uga.edu and Ryan Thompson at 706-542-4132 or rthomps1@uga.edu.
APPENDIX G

Figure G1. Ankle Bar Plots Participant Means of Kinematic Variables.

Very Mild = 1:6 Mild = 7:9 Moderate = 10:11
Figure G2. Knee Bar Plots Participant Means of Kinematic Variables.
Figure G3. Hip Bar Plots Participant Means of Kinematic Variables.

Very Mild = 1
Mild = 7
Moderate = 10
11
Figure G4. Bar Plots Participant Means of GRF Variables.
Figure G5. Bar Plots Participant Means of EMG Variables.