P04-6 ID210

LEG MUSCLE ACTIVATION PATTERNS DURING SIT-TO-STAND UNDER VARIABLE COMPLIANCE SURFACES

Vadim Zaika, Jennifer Romack, Shane Stecyk, Konstantinos Vrongistinos

California State University, Northridge, USA

The purpose of this study was to look if there were any differences in lower limb muscle activation patterns on various compliance surfaces during a sit-to-stand (STS) task. Previous studies have compared muscle activation patterns on stable versus unstable supporting surfaces but on the current research the surface stability was modified through four eight-way adjustable-stiffness shock absorbers mounted between two force plates creating stiffness conditions ranging from soft to very hard. Seventeen participants that were recruited randomly by a pool of volunteers performed a self-paced STS under eight surface stiffness conditions in randomized order. The mean EMG values of ten muscles during STS on various compliance surfaces were analysed and compared according under distinct phases of force profile. There were no statistically significant differences found in mean EMG of the muscles examined under different supporting surface stiffness conditions. It was found that muscle activation patterns during STS do not significantly change with variations of the surface compliance, suggesting that a STS movement skill is preprogramed, when the STS conditions are not known.

KEY WORDS: motor control, neuromechanics, stiffness.

INTRODUCTION: Training on variable compliant surfaces has been increasingly popular in training of athletes, clinical rehabilitation, and injury prevention programs. A great variety of equipment, such as inflatable balls, foam mats, wobble boards and balance discs has been developed for an unstable surface training (UST) (Cressey, et al., 2007). It has been advocated that muscle activation patterns change upon changing of the supporting surface stiffness (Tung, et al., 2010). It is also suggested that UST promotes increased muscle activity (Imai, et al., 2010), and develops balance and mobility at the same time by improving joint stability and rate of force development. As expected, training on various compliance surfaces is being commonly used to improve balance, coordination, and neuromuscular recruitment (Maior, et al., 2009), and is particularly valued in clinical rehabilitation settings (Cressey et al., 2007). Still, the research studies pertaining to the effects of UST on muscle activity have been producing mixed results (Lehman, 2007), causing a certain extent of disagreement regarding its application and benefits. Thus, the effects of an unstable surface training on muscle activity remain uncertain (Maior et al., 2009).Previous studies have examined muscle activity patterns on various compliant surfaces (Imai et al., 2010; Lehman, 2007; Maior et al., 2009; Tung et al., 2010), but not during sit-to-stand task. Notably, standing up from a seated position is one of the most common and essential everyday tasks (Tung et al., 2010), and ability to stand up independently is a first step in retrieval of functional capacity for people with neuromuscular disorders. Cheng, et al. (2004) observed EMG activity of the lower limb muscles during STS task, but not on various compliance surfaces. Findings of studies associated with UST were not consistent (Cressey et al., 2007; Lehman, 2007), suggesting that it is still unclear how the compliant support surface may alter muscle activity (Lehman, 2007; Maior et al., 2009). It should be acknowledged that previous studies have only examined and compared muscle activity patterns on stable versus unstable supporting surfaces. To our knowledge, there was no previous research done that have investigated muscle activation patterns surface that varies across a wide range of stiffness values by manually changing rigidity of the supporting surface.

The purpose of this research project was to analyze leg muscle activation patterns during sit-to-stand task on various compliant surfaces. A new apparatus with four variable stiffness shock-absorbers was constructed to create an experimental model where the researchers could establish a baseline of average responses that may be utilized in future studies to expand on the research topic. It was hypothesized that executing sit-to-stand on various compliance surfaces would result in significantly different limb muscles activation patterns, specifically that more compliant surface would result in significantly greater leg muscle activation.

METHODS: Ten males and seven females were recruited randomly from a convenient sample of volunteer students. All participants completed an informed consent form approved by the human subjects review board at California State University, Northridge. It was confirmed that potential participants did not have any major injury within the last year. A 16 channel Delsys Myomonitor system (Delsys, Boston. MA) was used to collect the data. EMG sensors were attached to skin over five leg muscles: rectus femoris (RF), vastus lateralis (VL), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GA) on both right and left sides. A tri-axial accelerometer was affixed to the head. The EMG electrodes and the accelerometer were connected to a wireless transmitter mounted to the waist belt. The height of the chair was adjusted individually for each participant according to knee height. Two Kistler force plates (Kistler, Switzerland) were used to measure ground reaction forces. A seven camera MX Vicon system (Vicon-Peak, Oxford, UK) was used to collect the kinematic data. A Custom-built platform was used for experimental setup (see Figure 1). Stiffness of the supporting surface was modified by changing the settings of four eight-way adjustable Enidine shock absorbers (ITT - Enidine Inc., Orchard Park, New York, USA) fitted between the force plates. Shocks were randomly adjusted between eight different settings, ranging from “1” (very soft - unstable surface) to “8” (very firm - hard surface). Each participant had to perform sit-to-stand under all eight different surface stiffness conditions in a randomized design order. Participants knew that they had to execute a sit-to-stand under different surface conditions ranging from soft to hard, but they did not know the exact condition during the data. The purpose for the randomization was to avoid the bias response from a participant that could alter his or her reaction to the changed supporting surface stiffness condition. After all adjustments were made, the tested participant placed his/her feet on the force plate in parallel. Then participants were instructed to rise up from a chair at a self-paced comfortable speed upon looking into an LED light that were generated by the computer during the data collection process.

Surface stiffness was an independent variable, and mean EMG amplitudes were dependent variables. Synchronized data collection made it possible to combine EMG and kinetic data. Mean EMG values of ten leg muscles (five on left and five on right) were collected from all participants under eight different surface stiffness conditions. Each EMG signal was rectified and processed with a fourth order Butterworth linear envelope. For each muscle mean EMG values were split and analysed under eight distinct phases of the sit-to-stand force profile (see Figure 2). Data were analysed with two statistical methods using IBM SPSS Statistics 19 software. To test the hypothesis, a repeated measures ANOVAs were used to analyse 80 dependent variables (eight phases times 10 muscles) across eight different surface stiffness conditions (independent variable. Significance level was set at 0.05.

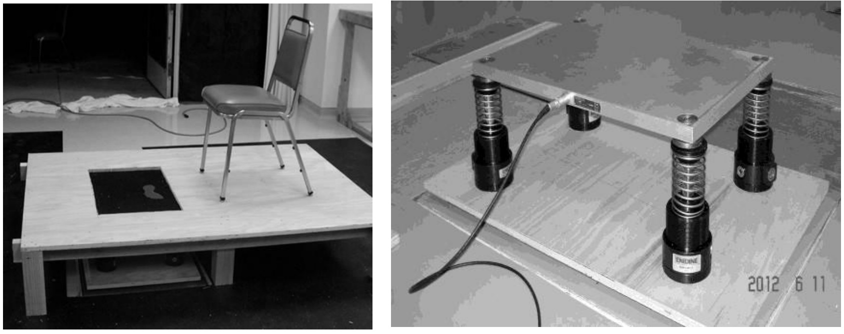

Figure 1. Experimental apparatus with variable stiffness shock absorbers.

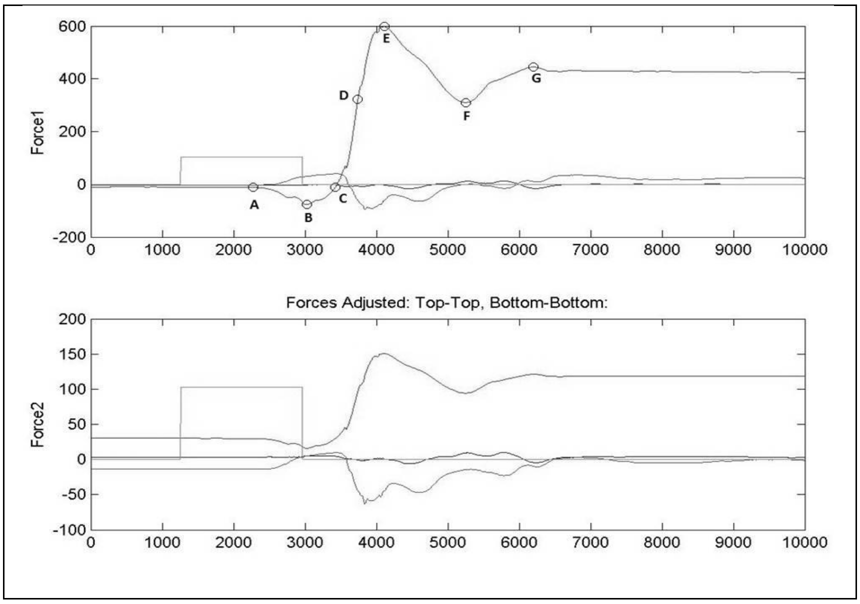

Figure 2. Sit-to-stand force phase diagram for top and bottom force plates. Force1 – top force plate, Force2 – bottom force plate. A is force onset, B is minimum reaction force, C is point where forces are positive again, D is point where positive impulse balances with negative impulse from A to C, E is when maximum force is generated, F is where local minimum y, G is the start of balance and steady state. Phase 1 is time span from A to B points, phase 2 is time span from B to C points, phase 3 is time span from A to C points, phase 4 is time span from C to D points, phase 5 is time span from D to E points, phase 6 is time span from E to F points, phase 7 is time span from F to G points, and phase 8 is time span from C to E.

RESULTS and DISCUSSION: The descriptive data of the 17 participants included ten males and seven females (mean age 23.18 years old, mean height 170.18 cm, mean weight 73.03 kg). The 80 (eight phases by ten muscles) repeated measures ANOVA revealed no statistically significant difference in mean EMG activity of the muscles in the eight surface stiffness conditions ($p>.05$). Upon examination of Wilks' lambda multivariate tests it was determined that F values within subjects were not significantly different (see Table 1). Occasionally, there were some statistical significant differences among the eight stiffness conditions when the SPSS procedures were at the level of Repeated Simple Comparisons (condition 8 with condition 1, condition 8 with condition 2 etc.). However, never those comparisons were coupled with an overall multivariate F statistic significant result. Those comparisons were considered statistically random, and it was expected that at 0.05 with eighty statistical procedures to have four procedures being statistically significant by chance.

Table 1.
Example of F values corresponding with Wilks' lambda multivariate tests results for the left tibialis anterior, showing that none of the dependent variables on each force phase were significant different because of the eight different stiffness conditions.

Force Phase	F	Probability
1	2.484	.093
2	2.322	.110
3	.382	.893
4	1.734	.207
5	.548	.781
6	1.772	.199
7	.464	.840
8	2.772	.070

Post-processing examining left and right leg EMG activation showed high correlation between the two sides indicating that results were not random (see figure 3). The findings contradict with previous results by Maior et al. (2009) who found significantly greater leg muscle activation during squats performed on an unstable versus a stable surface, most likely because that study examined the muscle activity during repetitive squats, thus neuromuscular system had some time to adapt. The current study used shock absorbers that change the stiffness in the vertical dimension of movement and not in three-dimensions as Maior et al. (2009). The current results support the outcome of the research conducted by Dolbow et al. (2008) who observed no significant changes in firing pattern of VMO and VL on stable versus unstable surface, with conclusions of Lehman (2007), who suggested that training on an unstable surface does not always result into increased muscle activity and findings of Imai et al. (2010), supporting the proposition that influence of the surface stability on muscle activation may vary, depending on the particular muscle or exercise.

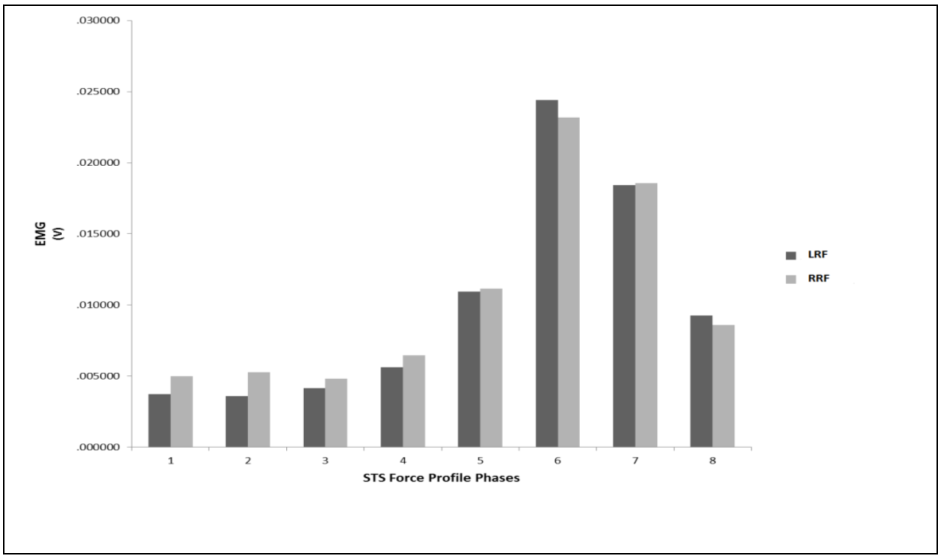

Figure 3. Average right and left rectus femoris activation patterns, across the eight phases of the STS force profile when socks are set at stiffness condition eight, showing statistically significant correlations between left and right sides, and no statistically significant differences. Abbreviations: LRF is left rectus femoris (dark shading), and RRF is right rectus femoris.

CONCLUSION: This study demonstrated that there is no muscular adaptation under variable stiffness conditions when such conditions are unknown and when stiffness variability is restricted in the vertical dimension. It seems that there is a preprogramed average response if participants are not preconditioned on the environment. So coaches may rely on unstable surfaces for training, but conditions during competition can be unpredictable.

REFERENCES:

Cheng, P., Chen, C., Wang, C., & Hong, W. (2004). Leg muscle activation patterns of sit-to-stand movement in stroke patients. *American Journal of Physical Medicine & Rehabilitation*, 83(1), 10-16.

Cressey, E., West, C., Tiberio, D., Kraemer, W., & Maresh, C. (2007). The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. *Journal Of Strength & Conditioning Research,21*(2), 561-567.

Dolbow, D., Gibson, E., Nguyen, T., Robertson, D., Sells, P., & Voight, M. (2008). Time of activation of quadriceps muscles during free squats on stable and unstable surfaces. Clinical Kinesiology: Journal of the American Kinesiotherapy Association, 62(1), 4-8.

Imai, A., Kaneoka, K., Okubo, Y., Shiina, I., Tatsumura, M., Izumi, S., & Shiraki, H.

(2010). Trunk muscle activity during lumbar stabilization exercises on both astable and unstable surface. *Journal of Orthopaedic & Sports Physical Therapy*, 40(6), 369-375.

Lehman, G. (2007). An unstable support surface is not a sufficient condition for increases in muscle activity during rehabilitation exercise. Journal of Canadian Chiropractic Association, 51(3), 139-143.

Maior, A., Simão, R., Freitas de Salles, B., Miranda, H., Costa, P. (2009). Neuromuscular activity during squat exercise on an unstable platform. *Brazilian Journal of Biomotricity, 3*(2), 121-129.

Tung, F., Yang, Y., Lee, C., & Wang, R. (2010). Balance outcomes after additional sit-to-stand training in subjects with stroke: a randomized controlled trial. *Clinical Rehabilitation*, 24(6), 533-542.