EFFECT OF RUNNING SPEED AND SURFACE INCLINATION ON MUSCLE ACTIVATION DURING TREADMILL RUNNING BY WOMEN.

Randall L. Jensen, Sarah K. Leissring, and Mitchell L. Stephenson
School of Health & Human Performance, Northern Michigan University
Marquette, MI, USA

The current study examined muscle activity of the biceps femoris (BF), semimembranosus (ST), vastus lateralis (VL), vastus medialis (VM), lateral gastrocnemius (GL), and medial gastrocnemius (GM) during treadmill running. Female college runners (n=15) ran at speeds of 1.79, 2.24, and 2.68 m·s^{-1} at 3 different grades of incline (0, 10, and 15%). Right leg Muscle activity was assessed via electromyography and normalized to maximal voluntary isometric contraction. Results indicated muscle activity increased with speed and grade except for SM which showed only grades of 0 and 15% being different; and that for GL and SM only 2.68 m·s^{-1} differed from other speeds. Muscles of the posterior thigh (BF and SM) were different from the posterior shank (GL and GM); while anterior thigh muscles (VL and VM) did not differ from the others. There were no differences in medial/lateral aspects.

KEYWORDS: electromyography, knee injury, EMG

INTRODUCTION: Women are almost twice as likely as men to sustain running injuries such as patellofemoral pain syndrome (PFP) or iliotibial band syndrome (Ferber et al., 2003). Thomeé et al. (1999) state that a common cause of PFP is malalignment/tracking of the patella and/or muscle imbalances. Lower extremity joint kinematics have been analyzed using varying grades of incline and running speeds (Chumanov et al., 2008). However, although kinematics were significantly different between sexes there were no significant differences across the varying speeds and grades of incline. Conversely muscle activation of the vastus lateralis and gluteus maximus did increase with increasing speed and incline. Chumanov et al. (2008) noted that as the challenge of a task increases, males and females utilize different neuromuscular strategies. Ferber et al. (2003) also found women displayed significantly greater peak hip adduction and hip internal rotation when compared to men. Dierks and coworkers (2011) found that while there was no difference in sagittal plane kinematics of runners with and without PFP, differences in frontal plane kinematics were evident. Others have noted that changing activity of the muscles with inclination depends on muscle location (Wall-Scheffler et al., 2010). They identified increased activity of hip adductors, but no change in hamstring activity with changes in speed while running at incline. These differences may influence abnormal tracking of the patella and resultant patellofemoral pain (Ferber, et al., 2003).
As noted above, muscle activity of the legs has been studied at varying speeds and grades, but not when comparing medial and lateral aspects of the leg. Thus, the current study assessed muscle activity of the medial/lateral leg, as well as antero/posterior aspects of the lower extremity while running at different speeds and inclines. It was hypothesized that increased speed and/or grade would alter muscle activity, specifically medial/lateral and antero/posterior.

METHOD: Fifteen female university runners (Mean ± SD: Age = 20.9 ± 1.0 y; weight = 61.0 ± 4.3 kg; height = 167.1 ± 5.8 cm; running history = 4.0 ± 2.7 h·wk^{-1}) volunteered to participate in the study. Participants signed an informed consent form and completed a Physical Activity Readiness-Questionnaire prior to participating in the study. Approval by the Institutional Review Board was obtained prior to commencing the study.
Participants ran nine, 1 minute, trials on a treadmill in random order: consisting of 3 different speeds (1.79, 2.24, and 2.68 m·s^{-1}) at 3 different grades of incline (0, 10, and 15%). Muscle activity was assessed via electromyography (EMG) of the vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), semitendinosus (ST), lateral gastrocnemius (GL), and medial gastrocnemius (GM) of the right leg. The electrode sites were prepared by abrading the epidermal skin layer, and swabbing the sites with isopropyl alcohol to reduce impedance

of the skin to < 5 kilo ohms. Disposable self-adhesive Ag/AgCl dual electrodes (Noraxon, Scottsdale, AZ, USA) were placed on the muscle bellies according to Cram et al (1997).
EMG data were collected at 1000 Hz via BTS 300 FREEEMG (BTS Biomedical; Milan, Italy). Raw data were band pass filtered at 10-450 Hz, full wave rectified, and integrated with a 50 millisecond moving window. Muscle activity was determined by averaging five cycles of muscle activity according to Kadaba et al. (1989). The onset and offset of muscle activity was determined by the activation threshold; defined as two standard deviations above the mean baseline signal at rest. Muscle activity was normalized to maximal voluntary contraction.
Statistical analyses via SPSS 22 consisted of a 6X3X3 Repeated Measures ANOVA examining muscle X speed X incline. Greenhouse-Geiser corrections were made if Sphericity was violated; Bonferroni's corrections were used for pairwise comparisons with alpha; $p = 0.05$.

RESULTS: Repeated Measures ANOVA for each muscle showed that activity increased with speed and grade (Figure 1). Exceptions were that for SM only 0 and 15% differed across grades; and that for GL and SM only 2.68 $m \cdot s^{-1}$ differed from other speeds. In addition, muscles of the posterior thigh (BF and SM) differed ($p < 0.02$) from the posterior shank (GL and GM); while the anterior thigh muscles (VL and VM) did not differ from the others ($p > 0.1$). There were no differences ($p > 0.9$) between muscles of the medial and lateral sides for the shank, anterior, or posterior aspects of the thigh.

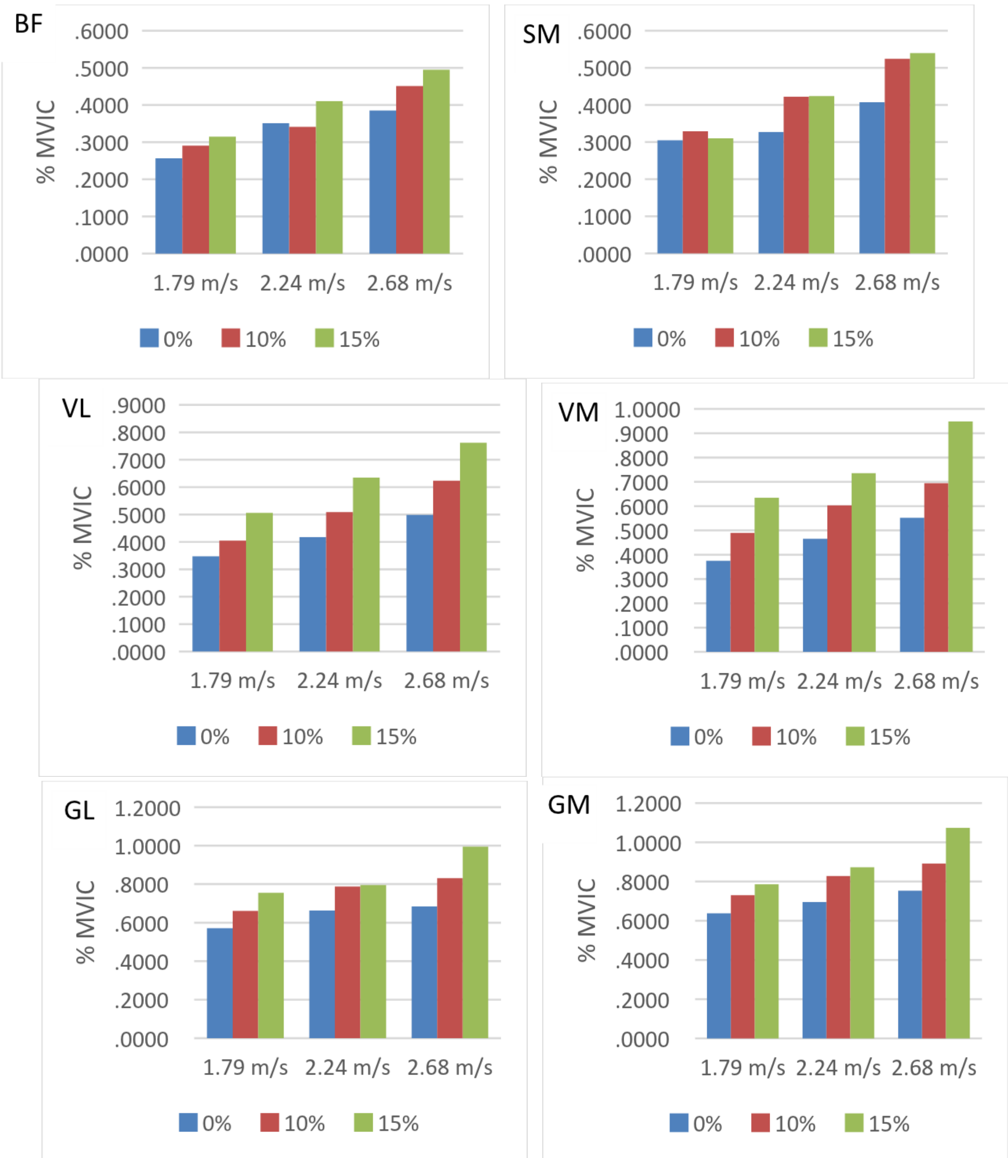

Figure 1. Muscle activation as a percentage of Maximal Voluntary Isometric Contraction (% MVIC) for Biceps Femoris (BF), Semimembranosis (SM), Vastus Lateralis (VL), Vastus Medialis (VM) Gastrocnemius Lateralis (GL), and Gastrocnemius Medialis, (GM) during running at grades of 0, 10, and 15 % and speeds of 1.79, 2.28, and 2.68 m/s.

DISCUSSION: Results of the study indicate that the hypothesis was partially rejected. Muscle activity did differ antero/posteriorly and across speed and grade, but not medial/laterally. The EMG activity of medial and lateral muscles did not differ, which suggests a lack of movement in the frontal plane. This finding supports the results of Chumanov et al. (2008) who reported no changes in frontal plane movement with increasing grade or speed. Chumanov and colleagues (2008) found increased muscle activity in the vastus lateralis with increased grade, however, they did not study the vastus medialis. It is likely that an equal increase of muscle activity on both lateral and medial sides of the leg would result in no frontal plane movement.

Furthermore as running speed and incline increased so did activity of all the muscles studied, relative to MVIC. This is was in agreement with the hypothesis and not unexpected as increased muscle activity is typically related to increased mechanical load (Belli, et al., 2002; Ferber et al., 2003; Swanson & Caldwell, 2000; Wall-Scheffler et al., 2010). Similar rationale has been suggested for the increase in EMG activity with increased running speed. Chumanov and colleagues (2008) found a greater activation in the vastus lateralis and gluteus medius with increasing grades of incline. Swanson and Caldwell (2000) found that the gastrocnemius (no differentiation for medial/lateral), medial hamstrings and BF were all more active during inclined running (30%) compared to level. This agrees with the current study where all muscles increased activity during inclined running. Conversely, Swanson and Caldwell (2000) found no change for activity of the vastus lateralis with increased grade. Wall-Scheffler and colleagues (2010) reported that increasing muscular activity was dependent on location, as they found that hamstring muscle (medial and lateral) activity did not change at incline with speed, while quadriceps, rectus femoris and vastus lateralis, muscle activity did increase. Wall-Scheffler and coworkers (2010) did not study the vastus medialis, it is likely that its muscle activity increased similar to the other quadriceps muscles.

The current study found that muscular activity of the posterior shank (GL and GM) was higher than muscles of the posterior thigh (BF and SM). Vasti muscles of the anterior thigh were intermediate and not different from either the posterior thigh or shank. Kyröläinen and coworkers (1999) noted the importance of the plantar flexors in running and this is supported by the current findings. Results of the current study suggest that, relative to MVIC, the calf muscles are the most active when running faster and/or uphill of the muscles studied.

CONCLUSION: The lack of differences in muscle activity between medial and lateral aspects of the lower extremity would indicate that other factors are likely the cause of running injuries such as patellofemoral pain syndrome (PFP) or iliotibial band syndrome. In addition, posterior muscles of the shank appear to contribute more in the adaptation to both faster speed and higher grades.

REFERENCES:

Belli, A, Kyröläinen, H, & Komi, PV. (2002). Moment and power of lower limb joints in running. *International Journal of Sports Medicine* 23:136-141.

Chumanov, ES, Wall-Scheffler, C, & Heiderscheit, BC. (2008) Gender differences in walking and running on level and inclined surfaces. *Clinical Biomechanics* 23:1260-1268.

Cram, JR, Kasman, G, & Holtz J. (1997). *Introduction to Surface EMG*. Aspen Publications: New York, NY, USA.

Dierks, TA, Manal, KT, Hamill, J, & Davis, I. (2011) Lower extremity kinematics in runners with patellofemoral pain during a prolonged run. *Medicine and Science in Sports and Exercise* 43:693-700.

Ferber, R, McClay Davis, I, & Williams, DS. (2003) Gender differences in lower extremity mechanics during running. *Clinical Biomechanics* 18:350-357.

Kadaba, MP, Ramakrishnan, HK, Wootten, ME, Gainey J, Gorton, G, & Cochran, GV. (1989) Repeatability of kinematic, kinetic, and electromyographic data in normal adult gait. *Journal of Orthopaedic Research* 7:849–860.

Kyröläinen, H, Komi, PV, & Belli, A. (1999) Changes in muscle activity patterns and kinetics with increasing running speed. *Journal of Strength and Conditioning Research* 13:400–406.

Swanson, SC and Caldwell, GE. (2000) An integrated biomechanical analysis of high speed incline and level treadmill running. *Medicine and Science in Sports and Exercise* 32:1146–1155.

Thomeé, R, Augustsson, J, & Karlsson, J. (1999) Patellofemoral pain syndrome: A review of current issues. *Sports Medicine* 28: 245-262.

Wall-Scheffler, CW, Chumanov, E, Steudel-Numbers, K & Heiderscheit, B. (2010) Electromyography activity across gait and incline: The impact of muscular activity on human morphology. *American Journal of Physical Anthropology* 143:601–611.

Acknowledgment
This study was supported in part by the Northern Michigan University College of Health Sciences and Professional Studies.