ANKLE & KNEE MUSCULATURE CO-CONTRACTION FOLLOWING EXTENDED DURATIONS OF WALKING IN WORKBOOTS

Chip Wade¹, John C. Garner²

¹Department of Industrial and Systems Engineering, Auburn University, Auburn, AL, USA
²Department of Health and Exercise Science, University of Mississippi Oxford, MS, USA

email: cwade1@auburn.edu, web: http://www.eng.auburn.edu/department/ie/ose/
email: jcgarner@olemiss.edu, web: http://www.olemiss.edu/depts/hesrm

INTRODUCTION

Much human gait research has been conducted on smooth level surfaces [1], for obvious reasons. A vast majority of activities of daily living occur on flat ground. However, much of the research is conducted in footwear that is typically used in activities of daily living (ADL) rather than in a work setting. The types of footwear worn for ADL are often designed primarily for comfort and/or aesthetics. Whereas footwear worn and designed for a work setting are often times meant for safety and stability. These differences in footwear would, in turn, potentially impact gait characteristics over time. The purpose of this study was to examine changes in muscle activity over an extended duration of walking exposure in work boots.

METHODS

Sixteen healthy adult males (height: 176.18 ± 29.19 cm; mass: 84.08 ± 11.68 kg; age: 28.50 ± 9.63 years) were recruited based on an anthropometric blocked assignment for participation in this study. Written informed consent approved by the Institutional Review Board was obtained prior to participation. Exclusionary criteria included neurological, orthopedic, cardiovascular, pulmonary abnormalities as well as any other difficulties hindering normal gait and/or balance. Participants wore the same brand and model of steel toed work boots, which complied with the ANSI Z41-1991 standards; oil resistant soles, distinct heels, steel toes, and the ability to lace above 15.24 cm. Participants were instructed to walk at a self-selected pace for a total of four hours along a flat hard vinyl surface which measured 25’x14’. The surface was of typical hardness as a worker would encounter in a manufacturing setting. Participants walked for the assigned incremented duration followed immediately by the testing protocol, with the cycle repeated for each exposure level. The participants were allowed no rest period between testing protocols and the following exposure period. The study used a repeated-measures design with exposure as a nine level independent variable: 1 hour, 2 hours, 3 hours, 4 hours of walking exposure, each associated with a pre-test (0 min).

The testing protocol consisted of the following. After preparations, participants were instructed to look straight ahead and walk naturally at a self-selected, comfortable pace across the assigned surface. Prior to each trial, participants returned to the starting position, waited for a period of one minute, and then were instructed to repeat the trial, for a total of 5 successful trials.

EMG data were recorded from selected muscles in the dominant stance (right/leading) leg, including the Vastus Medialis (VM), Medial Hamstring (MH), Tibialis Anterior (TA), Medial head of Gastrocnemius (MG), Peroneus Brevis (PB), Flexor Hallucis Longus (FHL) using a Noraxon Telemyo 8-channel electromyography system with a hardware band pass filter (10–500 Hz). Proper electrode placement was confirmed using a submaximal exertion test, followed by a Maximum Voluntary Contraction (MVC) test, which was utilized for normalization across subjects. EMGs were rectified and low-pass filtered at 50 Hz using a phaseless elliptical filter, then time normalized with respect to the stance leg with 0% being heel contact (HC) and 100% as toe off (TO). In addition, the EMG channels were peak normalized within subject using the MVC of each muscle. Gait cycle events [HC, midstance (MS), and TO] were determined via force plate activation (20N force) and marked accordingly within the data to identify gait cycles. Co-contraction index (CCI) was calculated based on...
the integrated ratio of the EMG activity (from -20% to 20% into stance, with HC being 0%; 30% to 70% into stance, with FF being 50%; from 80% to 120% into stance, with TO being 100%) of antagonist/agonist muscle pairs (TA/MG, VM/MH, PB/FHL) using the following equation [2]:

$$CCI = \frac{\text{Lower EMG}_i}{\text{Higher EMG}_i} \times (\text{Lower EMG}_i + \text{Higher EMG}_i)$$

Dependent measures were evaluated using a 2 X 4 (test [pre v. post]) X (exposure level [1 hour v. 2 hours v. 3 hours v. 4 hours] repeated measures analysis of variance (ANOVA), independently for the three CCI groups (TA/MG, VM/MH, PB/FHL). For all analyses, a significance level of $a = .05$ was set.

RESULTS AND DISCUSSION

Co-contraction was seen in the three antagonistic muscle pairs examined, and duration of walking had a significant effect on the co-contraction level (Figure 1). The CCI’s were significantly different across exposure durations for ankle inversion/eversion (PB/FHL), ankle dorsiflexion/plantarflexion (TA/MG) and knee flexion/extension (VM/MH). These CCI changes were found consistently at the three times in the step cycle (HC, MS, and TO).

The EMG analysis found high co-contraction as duration of walking increased, providing insight into a possible underlying control mechanism while walking for extended durations in work boots. It has been noted in previous research that antagonist muscle co-activation assists in providing a defense against external impact forces. In addition, antagonist muscle co-activation has been shown to be important to ensure a systematic distribution of compression forces across the articular surface of the joint. Furthermore, individuals utilize co-contraction in order to perform activities with demands that are higher relative to their capability [3]. In this context, muscular co-contraction would simplify the task by reducing the amount of reactive forces within the musculoskeletal system.

CONCLUSIONS

Our findings are consistent with the exiting literature related to muscle activation patterns and co-contraction indices. It appears that walking for prolonged durations increases muscle activation to control the moments at the joints of the lower extremity, potentially increasing both localized muscle fatigue and the compressive loading on those joints.

Figure 1. Co-Contract Index for ratios of the EMG activity of antagonist/agonist muscle pairs (VM/MH TA/MG, PB/FHL) at heel contact (HC), Mid-stance (MS) and Toe off (TO). *Pre to 4 hours from left to right on axis.

REFERENCES