Muscle fatigue and discomfort associated with standing and walking: Comparison of work surfaces.

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Localized muscle fatigue and perception of fatigue/discomfort in the lower legs induced by a 5 hour standing work task were evaluated for 3 different work surfaces (linoleum tiles on concrete floor, rubber mat, sole insert) in young adults and older individuals. Muscle fatigue was quantified by the muscle twitch force (MTF) magnitude and subjective ratings. The results indicate that the work task induces fatigue in lower leg muscles and this fatigue is similar for both age groups. Recovery from fatigue 1-hour post work was partial only and was greater for the younger than for the older participants. In other words, fatigue persisted and tended to persist longer for the older than the younger individuals. For younger individuals the long lasting effects of fatigue (0.5 hour post work) tended to be more pronounced on the laboratory floor and the mat than on the sole inserts and recovery (1 hour post work) tended to be more pronounced for the sole inserts than the other surfaces. For older individuals the long lasting effects of fatigue and recovery were similar for all surfaces. Fatigue was not significant on the control day. Generally, subjective perception of fatigue/discomfort in the feet and lower back tended to increase with time during the work task and was negligible 1-hour post work as well as on the control day. However, subjective and objective measures are not highly correlated since dissociations exist for both younger and older individuals. Hence, the results strongly suggest that reduction of leg muscle fatigue may not be adequately achieved by the use of at least some work mats or shoes. In addition, perception of fatigue/discomfort is an inappropriate indicator of long-term health effects and for the evaluation of muscle fatigue on work surfaces. Although perception of better comfort may have a positive influence on workers this does not resolve the issue.

Practitioner Summary: standing work induces lower limb muscle fatigue with long lasting effects not consciously perceived. Floor mats or sole inserts do not appear to mitigate muscle fatigue. Age effects are not conspicuous in this context of low level sustained exertion.

Keywords: muscle fatigue, standing work, work surface, muscle twitch force, discomfort, age

1. Introduction

Standing work is quite common in service industry as well as in manufacturing industries. The recent European survey of working conditions (Parent-Thirion et al., 2012) show that more than 50% of the workers stand at least ¾ of their work time. Prolonged standing has been associated with low back pain and disorders (Waters and Dick, 2014; Callaghan, 2008) as well as other symptoms affecting the legs (D’Souza et al. 2005; Elsner et al. 1996). Anti fatigue devices have been advocated to mitigate fatigue (Cham and Redfern, 2001); however, the few studies testing their efficiency relied on quantification methods sensitive only to the short term effects of fatigue. Specific methods have been developed to quantify localized muscle fatigue resulting from sustained or intermittent muscle exertions and reveal the long lasting effects of fatigue( e.g., Edward et al., 1977; Blangsted et al., 2004; Adamo et al., 2002), that may persist up to 24 hours (Edward et al. 1977).

Long-term fatigue associated with low force exertions has been investigated in the upper limb (Adamo et al., 2002; Sogard et al., 2003), however little is known about this type of fatigue in the lower limb. Hence, this study investigated the long lasting effects of fatigue resulting from standing and walking over different floor surfaces, or with and without sole inserts while performing a standing work task for 5 hours. The goals of the study were to assess muscle fatigue and to determine the eventual reduction in muscle fatigue by sole inserts or a rubber mat. Fatigue in lower leg muscles was assessed by the measure of the muscle twitch
force magnitude induced by electrical stimulation and the subjective perception of fatigue/discomfort in the lower limbs and low back areas.

2. Methods

2.1 Participants

Ten young (18-30, 8 males, 2 females) and six older (55-65, 1 male, 5 females) individuals participated in the study. All participants were in good health, actively involved in occupational and recreational activities and free from any neurological and musculoskeletal impairment that might influence their ability to perform the standing work tasks. Prior to their inclusion in the study, all participants signed an informed consent agreement approved by the internal review board of the University of Michigan.

2.2 Twitch force measurement and recording

The apparatus and method used to record the muscle twitch force (MTF) were developed in an earlier study (Adamo et al., 2002) and adapted for the present investigation. The subjects were comfortably seated in a semi reclined posture, the left foot resting on a footplate equipped with a load cell fixed to an adjustable support. The leg posture corresponded to a 90° ankle flexion with the knee extended at about 120°, so that no voluntary effort was required to maintain the leg or foot position (Fig. 1). The load cell, whose location corresponded to the first metatarsal phalanx, measured twitch forces in response to sub-maximal electrical stimulation of the gastrocnemius-soleus muscles. A lateral support of the foot prevented horizontal displacements and facilitated precise repositioning. The resolution of the load cell was 0.05 N and the force signal was sampled at 1000 Hz. The optimal location of the stimulation electrode (8 mm, Ag/AgCl) was determined by finding the region corresponding to the maximum twitch force with tolerable discomfort for the duration of the stimulation period (3 – 4 min). This location was clearly marked for replacement of the electrode on subsequent days. For each participant, the same stimulation intensity was used for all tests. Overall, across participants, the stimulation intensity used to elicit individual muscle twitches ranged from 30 to 40 mA for the selected pulse duration of 1ms. The electrical pulses were delivered at a frequency of 2 Hz through a Grass medical stimulator (GS880) connected to an isolation unit (SIU5) and a constant current unit (CCU1A). An 18 mm pre-gelled Ag/AgCl ground electrode was placed over the left patella.

![Muscle Twitch Force measurement apparatus](image)

Figure 1. Muscle Twitch Force measurement apparatus. Twitch force in the gastrocnemius-soleus muscles was elicited by electrical stimulation of the muscle and recorded by a load cell supporting the footrest.

2.3 Work Tasks and surface conditions

Participants were standing in an upright posture and performed various light manual tasks on a work bench adjusted to elbow height to prevent forward bending (torso flexion). Supporting the arms on the work bench
was not allowed. The tasks were performed over a five hour period including a 5 min rest break at the end of the first, second and fourth hour, and a 30 min break at the end of the third hour. During the rest periods the participant was free to leave the workstation and seat in a comfortable armchair. All participants were provided the same type of new sport shoes and the same type of new sole insert. The standing tasks were performed in three floor conditions presented in a random order: 1) linoleum tiles on concrete corresponding to the laboratory floor; 2) Nitrile rubber mat (3/4” thickness, hardness rating about 50-55); 3) sole insert on lab floor. A fourth condition corresponded to a reference in which the participant was not submitted to any work task and remained mostly seated.

2.4 Procedure

All subjects were instructed to minimize physical exertions 24 hours prior to the experiment. On the first experimental day, the subjects were introduced to the experimental protocol, electrical stimulation procedures and signed the consent forms. All subjects were exposed to one of the three randomly assigned standing work conditions (concrete floor, mat or sole inset) presented on non-consecutive days and the control condition on a fourth experimental day. For each experimental day, the objective measures of fatigue (MTF) was evaluated before, at mid work time (2.5 hour after start of work), immediately after work and then 30, and 60 minutes after the end of the work task. The subjective rating of fatigue was performed before, at mid work time and only immediately after work (see Fig. 2) since this perception is known to be of short duration.

Figure 2. Test schedule. The duration of the work period is 5 hours. Rest break were matching common practice (see text). Vertical bars indicate measurement times. The time line is relative to the initial measure before work (control) and work period W (FR = fatigue rating, MTF= muscle twitch force measure).

2.5 Muscle twitch force

For each MTF measurement, first the muscle was stimulated for 120 and 180 seconds to reach the stable state of the twitch force after potentiation. Then, trains of 30 twitches delivered at the frequency of 2 Hz were administered until three trains with a coefficient of variation of less than 5% were obtained. The twitch force, defined as the difference between individual peak and baseline force levels was averaged over each train of 30 twitches and the average of the three trains determined the twitch force for that measurement time period.

2.6 Subjective evaluation of muscle fatigue

Subjective perceptions of localized muscle fatigue/discomfort in both legs (foot, lower leg, knee, upper leg) buttock and lower back were rated by placing a mark on visual analog scales associated with a representation of the body.

2.7 Data analysis

An ANOVA was conducted to determine the main effects of age (young, old), surface condition (concrete, mat, sole) or interactions on the MTF response at selected time measurement periods. Two post-hoc analyses were also included. The Tukey-Kramer method was used to identify differences across work tasks and between the age groups and paired t-tests were used to determine whether there were within group
differences between pre- and post-work MTF measures. Fatigue was quantified by the decrease in MTF, relative to the baseline measure obtained before each work task (% baseline). Comparisons between tasks were restricted to selected synchronous measures as an ANOVA including all time intervals, conditions. An ANOVA was also performed on subjective rating measures.

3. Results
3.1 MTF

The decrease in MTF after the work task is significant (P < 0.05) for both younger and older individuals. Differences between age groups are not significant (P > 0.05). Recovery from fatigue 1 hour post work is greater for the young than the older participants, or in other words, fatigue tended to persist longer for the older than the younger individuals (Fig. 3A-B).

For younger individuals the long lasting effects of fatigue (30 min post work) tended to be more pronounced for the lab floor and mat than the sole, and recovery (1 hour post work) tended to be more pronounced for the sole than the other surfaces (Fig. 3A). For older individuals the long lasting effects of fatigue (30 min post work) and recovery (1 hour post work) were similar for all surfaces, as indicated by the absence of statistical significance (Fig. 3B).

3.2 Subjective perception of fatigue

Perception of fatigue/discomfort after the work task was similar for younger and older individuals with a general tendency to increase with work duration. Furthermore, perception of fatigue/discomfort was greater for the feet and lower back than for other lower body areas. However the influence of the work surface was not significant except for the feet. For young individuals, fatigue was less pronounced in the feet for the sole insert than the other work surfaces. For the older individuals fatigue perception in the feet remained the same over time and was less pronounced for the sole than the other surfaces at after the end of work.

4. Conclusions

The objective measure indicates that 1) fatigue increases during standing work, 2) none of the tested surfaces prevented or influenced the development of fatigue in the lower leg muscles over the 5 hours of standing work with rest breaks. Furthermore, appropriate sole inserts may reduce foot discomfort. Subjective and objective measures are not well correlated and dissociations exist for both younger and older individuals, where the long lasting effects of fatigue are not perceived. This dissociation has also been observed in a similar study (Garcia et al. 2015) and upper limb studies (Adamo et al. 2002, 2009). Hence, the results
strongly suggest that reduction of leg muscle fatigue may not be adequately achieved by the use of, as tested, a work mat or shoes. In addition, perception of fatigue/discomfort is an inappropriate indicator of long-term health effects and for the evaluation of muscle fatigue on work surfaces. Although perception of better comfort may have a positive influence on workers the corresponding type of mediation does not resolve the issue of lower leg fatigue.

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References


