The influence of pauses on the fatigue of upper limb muscles during the task of ironing

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Abstract
The aim of this study was to analyze the influence of position and pauses on muscle activity and fatigue during the task of ironing. Ten female participants performed the task of ironing in two different positions (standing and sitting) for 10 min each with a 1-min pause at the end of each task. Muscle activity and fatigue from the upper trapezium, anterior deltoid, and pectoralis major were analyzed using surface electromyography. The results showed that the positions had no significant influence on muscle activity; nevertheless, they had significant influence on muscular fatigue. In addition, the pausess were possibly beneficial in decreasing the muscle fatigue, but the results were not conclusive.

Keywords
Electromyography, muscle activity, repetitive movement, sitting position, standing position

Introduction
The relation between professional activities and health is very much a present day concern. Repetitive movements, incorrect postures, lack of pauses, and positions maintained over long periods can lead to fatigue that gives rise to a progressive reduction of capacity to work. This leads to an increased risk of musculoskeletal injuries that can cause important socioeconomic problems, such as the decline of production and the increase of absenteeism (Shanahan and Jezukaitis 2006; Ting 2007; Bodin et al. 2012). Musculoskeletal injuries are chronic pain syndromes, affecting one or more regions of the body. They often affect both the neck and upper limbs and can occur when performing a given professional activity that is repetitive, involves still postures as well as handling considerable loads (Harrington et al. 1998; Buckle and Devereux 2002). Occupational health policies in general establish that workers carrying out repetitive tasks for 60 min should have a recovery period. The American Conference of Governmental Industrial Hygienists (2008) recommends
pauses of 10 min per each 60 min of repetitive manual tasks. Hence, for repetitive working tasks, a work/recovery relationship of 5:1 is recommended. Micro pauses can only be considered effective when there is a complete 10-s pause in limb activity every 50 s (Jorgenson 1997). The pauses tend to increase the production, rather than reduce it, as it appears to prevent excessive fatigue. Situations where a worker accelerates his/her production efforts in order to have one longer recovery pause are not beneficial. Recovery is more effective when several pauses are distributed periodically throughout the working day (Dahlberg et al. 2004). Muscular fatigue may result from changes in the homeostasis of the muscle or from changes in the neural input that arrives at the muscle. Fatigue depends on the type, duration, and intensity of the activity, on the typology of the muscle fibers recruited, on the training level of the subject, and on the environmental conditions of the task being carried out (Hoe et al. 2012). Industries use production lines where the employees are frequently required to make short brisk movements. This usually leads to a dynamic overload of the upper limb muscles, and to a static overload in the shoulders and column (Hviid-Andersen et al. 2002). Clinically, the lesions are predominant in the cervical spine and upper limbs (Doyle and Towse 2002; Shanahan and Jezukaitis 2006). Chen and Lee (1994) reported high levels of pain and complaints of discomfort in the cervical column and in the shoulders of employees working at an industrial laundry. Ironing is a repetitive task both at the professional and domestic levels. This task is generally performed in the standing position; however, a sitting position may have some advantages, such as lower energy consumption and better posturing (Kroemer and Grandjean 2008). To the best of our knowledge, no study has examined the effects of the position and pauses in upper limb muscle activity during the task of ironing. During the movements involved in ironing, the upper limb has muscles that function as stabilizers and muscles that function as movement producers (Marieb and Hoehn 2004; Ludewing and Borstead 2005): the main stabilizer is the upper trapezius; the anterior deltoid is the major abductor; and the pectoralis major is the principle adductor. Hence, this study was designed to analyze the influence of the subject’s position (standing or sitting) on the muscular activity and fatigue of the upper trapezius, anterior deltoid, and pectoralis major during the task of ironing.

**Methods**

**Participants**
The sample consisted of 10 female university students aged between 20 and 24 years old without regular practice in ironing. Experienced subjects in the task of ironing were not included in order to prevent the interference of pre-acquired strategies and motor habits. Practitioners of sports were excluded, since they have greater resistance to fatigue, and also possible candidates that presented a neuromuscular-skeletal pathology were excluded as this condition could modify the movements executed as well as the recruitment of muscles during the movement. Only female participants were recruited, mainly because ironing is a task that is more frequently performed by women, whether at home or professionally (Bianchi et al. 2000). The study was approved by the local ethics committee and implemented according to the Declaration of Helsinki, the participation was voluntary, and all participants signed informed consent forms.

**Procedures**

The weight, height, body mass index (BMI), and the dominant arm of each participant were recorded as well as confirming they had no physical impairments. The electromyographic (EMG) activity was assessed using an MP 150 Workstation from Biopac Systems (Goleta, CA, USA), with steel electrodes (model TD150), and a bipolar configuration with 20 mm between the two detection surfaces and an earth electrode. The cutaneous surfaces were prepared to reduce electrical resistance. This was done by removing dead cells and nonconductive elements with alcohol and sandpaper (Turker 1993). The electrodes were placed in the midpoints of the muscle bulges: for the anterior deltoid, the electrodes were placed two fingers below the acromion; for the upper trapezium muscle, the electrodes were placed in the midpoint of the line between C7 and the acromion; and for the pectoralis major, the electrodes were placed two fingers below the midpoint of the clavicle line. The earth electrode was placed on the elbow. The task of ironing was performed with each subject in the standing and sitting positions. The sequence of positioning was chosen randomly for each participant, to avoid effects of pre-activity and/or learning. For the standing position, the ironing board was positioned according to the level of the trochanter with the iron 5 cm below the elbow. For the sitting position, the elbow was kept at 90 and the ironing table was placed immediately below the iron that was held by the subject. The EMG activities of the dominant arm muscles under study during the ironing task were recorded for 10 min. Before the ironing task began, maximal isometric contractions were measured in order to normalize the EMG signal (Lehman
and McGill 1999). Participants were requested to make three maximum isometric contractions for 5 s, with a 1-min break between repetitions (Brown and Weir 2001). For this procedure, the average root mean square (RMS) and the median of frequencies of the EMG signal between 1 and 4 s in the three repetitions were used for analysis. All procedures and verbal commands were transmitted in a standard way by the same person. The EMG signals of the ironing tasks were analyzed at three selected moments for 30 s each: start (0–30 s), end (30 s after 10 min of ironing), and after pause (30 s after a 1-min pause). The sampling of the EMG signals was performed at 1000 Hz. The EMG signals were pre-amplified in the electrodes, sent to a differential amplifier of adjustable gain (12–500 Hz; common mode rejection ratio (CMRR): 95 dB at 60 Hz and input impedance of 100 M), and recorded in a computer for analysis using Acqknowledge software (Biopac Systems). For each movement performed in each position, the RMS of the average EMG signals was analyzed to assess the respective level of muscular activity. The associated median frequency, that is, the frequency at which 50% of the total power is reached, was found by spectral analysis. The difference between the median frequencies at the start and end moments was calculated to assess muscular fatigue (Soderberg and Knutson 2000): the more negative the difference, the greater the fatigue. Differences in muscle activity were evaluated for the 2 positions (sitting, standing) 3 moments (start, end, after pause) using the Repeated-Measures ANOVA. In addition, t-tests for paired samples were used to verify if there were any differences between the positions for muscular fatigue. All statistical tests were two-tailed and a significance level of p ≤ 0.05 was adopted.

**Results**

The sample studied was composed of 10 female, unmarried, right-handed university students. The average age was 21.8 years old with a standard deviation (SD) of 1.033 and a BMI of 22.648 ± 2.742 (average ± SD). In abduction and adduction, the upper trapezium had a higher level of activity in the sitting position than in the standing position. There was always an activity increase from the beginning to the end of the task, and an activity decrease after the pause, except in the standing position. A recovery after the pause was not observed in the adduction (Figures 1 and 2). However, these differences in muscle activity were not significant over time for both adduction (F ¼ 0.473; p ¼ 0.551) and abduction (F ¼ 0.657; p ¼ 0.517). In addition, there
was no significant Position Time interactions for both adduction (F ¼ 0.297; p ¼ 0.654) and abduction (F ¼ 0.425; p ¼ 0.647).

The muscular activity of the anterior deltoid, which is responsible for the abduction, was higher in the standing position, which means that the standing position is less advantageous. In both positions, an increase of muscular activity was observed from the beginning to the end of the task, and a recovery and consequent reduction of the quantity of muscle activity were noted after the pause, bringing the activity level very close to its initial value (Figures 3 and 4). A significant difference was found in muscular activity over time for adduction (F ¼ 7.753; p ¼ 0.006). A post hoc test using the Bonferroni correction disclosed differences between the moments of start and end (p ¼ 0.44) and also between the moments of start and after pause (0.014) for this movement. However, no significant Position Time interaction (F ¼ 0.233; p ¼ 0.703) was found. In addition, no differences over time for abduction (F ¼ 0.203; p ¼ 0.778) and Position Time interaction (F ¼ 0.003; p ¼ 0.993) were found. The adduction of the pectoralis showed that the sitting position was less advantageous than the standing position as the correspondent muscular activity level was higher. In addition, from the beginning to the end of the task, the muscular activity increased; however, after the pause, there was a decrease in the activity level, and the recovery was more evident in the standing position (Figures 5 and 6). These differences in muscular activity were not significant over time for both adduction (F ¼ 0.962; p ¼ 0.389) and abduction (F ¼ 3.290; p ¼ 0.076). In addition, there was no significant Position Time interactions for both adduction (F ¼ 1.491; p ¼ 0.239) and abduction (F ¼ 0.049; p ¼ 0.874). Table I shows that there was higher muscular fatigue in the sitting position than in the standing position in the abduction movement for the upper trapezium (t ¼ 2.738; p ¼ 0.023). In addition, there was a trend towards more fatigue in the standing position for both the adduction movement of the deltoid (t ¼ 2.089; p ¼ 0.066) and the abduction movement of the grand pectoralis (t ¼ 1.907; p ¼ 0.089).

**Discussion**

We did not find any evidence supporting a clear advantage for one position over the other for the task of ironing. However, in terms of muscular fatigue, the sitting position was more disadvantageous for the anterior deltoid. Although the position (standing or sitting) influences the posture of the shoulders, which in turn interferes with the shoulder muscle activities (Aspden
we did not confirm this hypothesis for the ironing task. We found that 1-min pauses were not enough to significantly reduce the muscular activity after the task of ironing. The intense pace of work, lack of breaks, and long shifts can potentiate stress and consequently, increase the risk of musculoskeletal injuries (Jorgenson 1997; Rietveld et al. 2007). Pauses are thought to be important for muscle recovery and avoid fatigue. Consequently, when there are no pauses in repetitive tasks there is no recovery of muscle fatigue, and there is a decrease in production capacity and an increase in the risk of injury. Therefore, it is crucial to establish pauses during repetitive tasks (Bianchi et al. 2000; de Zwart et al. 2001). According to our findings, the pauses should be longer than 1 min during the task of ironing to produce recovery. The inability of a muscle to generate high levels of muscular strength or maintain these levels is known as neuromuscular fatigue (da Costa and Vieira 2010; Boyas and Guevel 2011). The upper trapezium displayed higher fatigue in the sitting position than in the standing position, although this did not occur in abduction. One explanation for this finding is that, in order to compensate for the contraction strength decrease of the fatigued fibers and maintain the level of active tension, motor units are triggered at higher speeds. This is more evident in sub-maximal contractions (Boyas and Guevel 2011). The anterior deltoid displayed higher fatigue in the sitting position during abduction. Minning et al. (2006) observed in their study that in addition to the anterior deltoid, the anterior serrate and the upper and lower trapezium presented fatigue during abduction. This may explain the fact that both upper trapezium and anterior deltoid muscles presented higher fatigue during abduction in the sitting position. Here in this study only the pectoralis major presented signs of fatigue in the standing position. Potential shortcomings of the present study include the fact that it was carried out with a group of female students as there are differences in EMG activity between men and women in terms of muscular fatigue (Doyle and Towse 2002; Russ and Kent-Braun 2003). However, women tend to occupy less differentiated and more repetitive work, which together with the hormonal issues and the duplication of labor and domestic tasks, increases the likelihood of musculoskeletal injuries in women (Jorgenson 1997; Bianchi et al. 2000; de Zwart et al. 2001; Dahlberg et al. 2004). The authors believe that future studies with more distal longitudinal assessments, larger samples, and involving experienced and non-experienced subjects are needed.
Figure 1. Average EMG RMS in adduction of the upper trapezius muscle in the standing and sitting positions at the beginning, end, and after the pause of the task.

Figure 2. Average EMG RMS in abduction of the upper trapezius muscle in the standing and sitting positions at the beginning, end, and after the pause of the task.

Figure 3. Average EMG RMS in adduction of the anterior deltoid in the standing and sitting positions at the beginning, end, and after the pause of the task.

Figure 4. Average EMG RMS in abduction of the anterior deltoid in the standing and sitting positions at the beginning, end, and after the pause of the task.
References

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