Neuromuscular Fatigue Characteristics in Female Painters Following the Working Day

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Abstract. The aim of this study was to evaluate changes in neuromuscular fatigue characteristics in painters following the working day. The subjects (n = 10) were female painters aged 22-60 years. First the subjects completed a questionnaire and thereafter they performed before and after the working day a 3-minute test of wall painting, in the course of which the electromyographical (EMG) power spectral median frequency (MF) for biceps brachii, trapezius, deltoideus and infraspinatus muscles was measured. The results indicated an increase in subjectively evaluated muscle fatigue compared to the beginning of the working day, whereas the most burdened regions were the arms and shoulders. Objectively estimated muscle fatigue emerged before and after the working day when comparing EMG power spectral MF measured at the beginning and end of the wall painting test. However, this muscle fatigue, evaluated objectively by EMG power spectrum MF slope from biceps brachii, trapezius, deltoideus and infraspinatus muscles, did not differ significantly before and after the working day. This study revealed that painters used different manners of work, whereas the working tool was the same for everyone and no-one had customized it for herself. It is also important to emphasize that 82% of the workers had not been guided in terms of ergonomics. The results of this study can be used by specialists of ergonomics.

Key words: Electromyography, muscle fatigue, neuromuscular function

INTRODUCTION

Epidemiological studies indicated that in shoulder joint, various disorders and injuries occur in the first place in case of working with arms elevated above the level of shoulders, as in such a position, the burden on the joint structure increases abruptly (Bjelle et al., 1973; Dan et al., 2001). The typical ailments of the shoulder joint are calcific tendinitis, tenosynovitis, arthritis and periarthritis. Each disease has a distinctive pathology and treatment regime (Neviaser, 1983). Garg et al. (2005) studied shoulder girdle muscle strength of one hand in women when working with hands elevated above the head. It was found that women, especially in those professions that require working with hands elevated above the head, have little strength in their shoulder muscles. Chow & Dickerson (2008) investigated shoulder strength as a function of hand location and force direction while sitting and standing. They found that there is a significant decrease in shoulder strength of females compared to males.

Muscle fatigue has been defined as a reduction in the force-generation capacity of a muscle due to previous activity (Edwards 1981; Bigland-Ritchie et al., 1986). It is associated with changes in amplitude as well as the power spectrum parameters of the electromyogram (EMG) over time. During sustained submaximal isometric contractions typical changes in surface EMG occur including an increase in root mean square and a spectral shift towards low frequency (spectral compression) (Löscher et al., 1994). Musculoskeletal discomfort can manifest itself as tension, muscle fatigue, soreness, etc. in and around active and passive structures, i.e. muscles, tendons and joints (Van der Grinten, 1992). Perceived musculoskeletal discomfort as subjective sensation of muscle fatigue can be measured by self-reports using the Borg Category Ratio (SR-10) Scale (Borg, 1990; Hamberg-van Reenan et al., 2009).

The aim of this study was to evaluate the changes in neuromuscular fatigue characteristics in painters following the working day. Measurements were carried out at the place of work at the beginning of and after the working day.

MATERIAL AND METHODS

Subjects

Ten females working as painters at (mean ±SE) age of 45.5±3.2 years participated in this study. The height, body mass and body mass index of the subjects were 162.4±2.6 cm, 80.1±4.8 kg and 30.3±1.4 kg m^{-2}, respectively, and their length of employment as painter was 21.3±4 years. The subjects were randomly selected and participated in this study voluntarily. The questionnaires and the measurements were completed in May and June, 2008. Larger facilities were chosen as the site of the measurements. Eight subjects were surveyed at the 1st stage of construction at the Tartu University Maarjamõisa centre of medical facilities and two subjects at the fashion and entertainment centre in downtown Tartu. The measurements were conducted at the beginning and at the end of the working day at the site where the workers were employed. The subjects did not have to leave the site and the working rhythm was disturbed as little as possible, thus yielding more reliable results. The height and body mass of the subjects were measured at the site with metal anthropometer and electronic scales, respectively. The subjects were familiarized with the essence and the aims of the survey.

Data collection

The measurements were conducted at the beginning and at the end of the working day at the site where the workers were employed. So the subjects did not have to leave the site and the working rhythm was disturbed as little as possible, thus yielding more reliable results. The height and body mass of the subjects were measured at the site with metal anthropometer and electronic scales, respectively. The body mass index (kg m^{-2}) of the subjects was also calculated. In the course of the research, subjects completed the questionnaire first. Subjective muscle fatigue sensation in hands, trunk, back and lower limbs was estimated with a psychophysical rating scale (Borg CR-10 Scale). The scale included numbers from 0 to 10. Perceived exertion was estimated in the following way: 0-2 weak, 3-4 moderate, 5-7 strong, 8-10 extremely strong fatigue. During the wall painting test,

the EMG power spectrum MF (Hz) was recorded from deltoideus, trapezius, infraspinatus and biceps brachii using 8 channel electromyograph ME 6000 (Mega Electronics, Finland). The data gained were processed with the computer application MegaWin (2007). When processing the data, the following intervals were taken out of the three-minute segment: from the beginning of the test a 10-20 s interval and from the end of test a 160-170 s interval. The same intervals were taken before and after the working day. EMG power spectrum MF slope (%•min kg^{-1}) was calculated according to the formula:

$$MF_{slope} = \frac{(MF_b - MF_a) \cdot t}{MF_b \cdot P \cdot 60} \cdot 100,$$

whereas *MFb* is a EMG power spectrum median frequency at the beginning of the working day, *MFa* is a median frequency after the working day, *t* is a test time (3-minutes) and *P* is the weight of the extension pole (3.2 kg). The selection of the muscles depended on the nature of the wall painting exercise. The single-used surface EMG electrodes (Leonhard Long GmbH) were attached on the subjects by a female assistant who had been instructed correspondingly.

Statistical analysis

Data are expressed as means and standard errors (±SE). One-way analysis of variance (ANOVA) was used to test the differences in measured parameters before and after the working day and at the beginning and at the end of the wall painting test. When the significant main effect was found with ANOVA′, the Bonferroni post hoc procedure tested for establishing differences among mean values. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS AND DISCUSSION

During the 3-minute wall colouring test (Fig. 1), EMG power spectral activity MF slope did not change significantly but there was objectively estimated muscle fatigue when comparing the beginning of the working day and the end of the working day (Fig. 2). This can be related to the fact that at the beginning of the working day, the muscles have not yet reached their working capacity. EMG power spectrum median frequency (MF) slope (Fig. 3) of the measured muscle groups did not differ significantly ($p>0.05$) at the beginning and after the working day.

Fig. 1. Performing a 3-minute wall painting test.

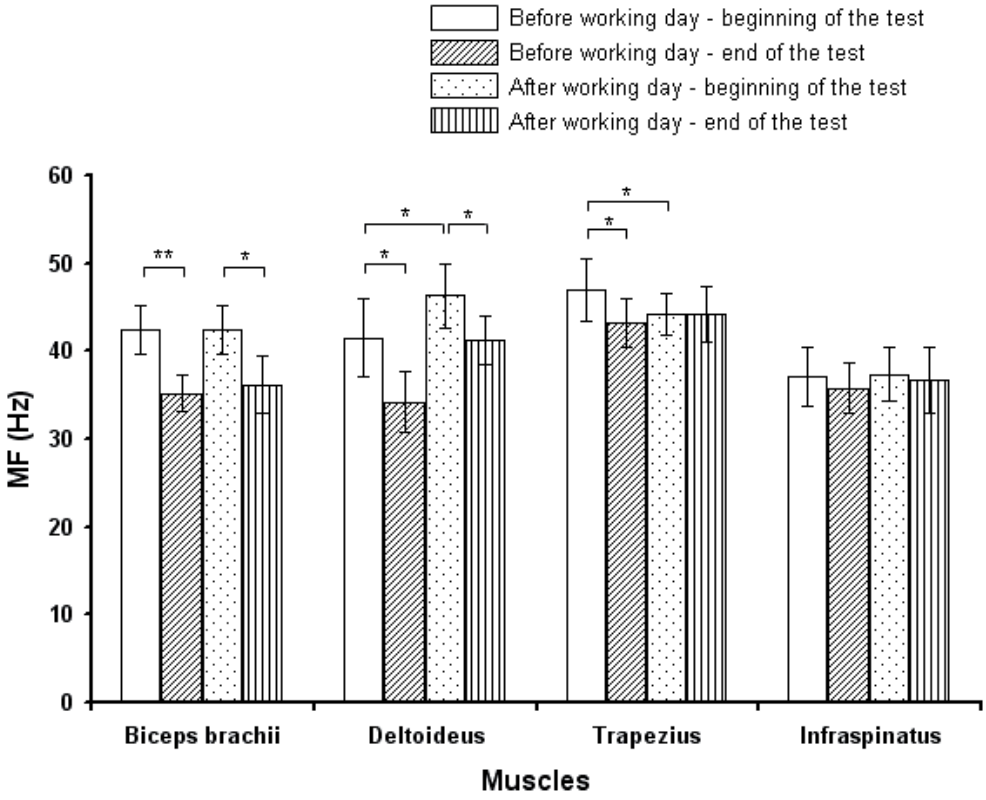

Fig. 2. The electromyogram power spectrum median frequency (MF) at the beginning and end of a 3-minute wall painting test before and after the working day (mean ± SE). * $p<0.05$.

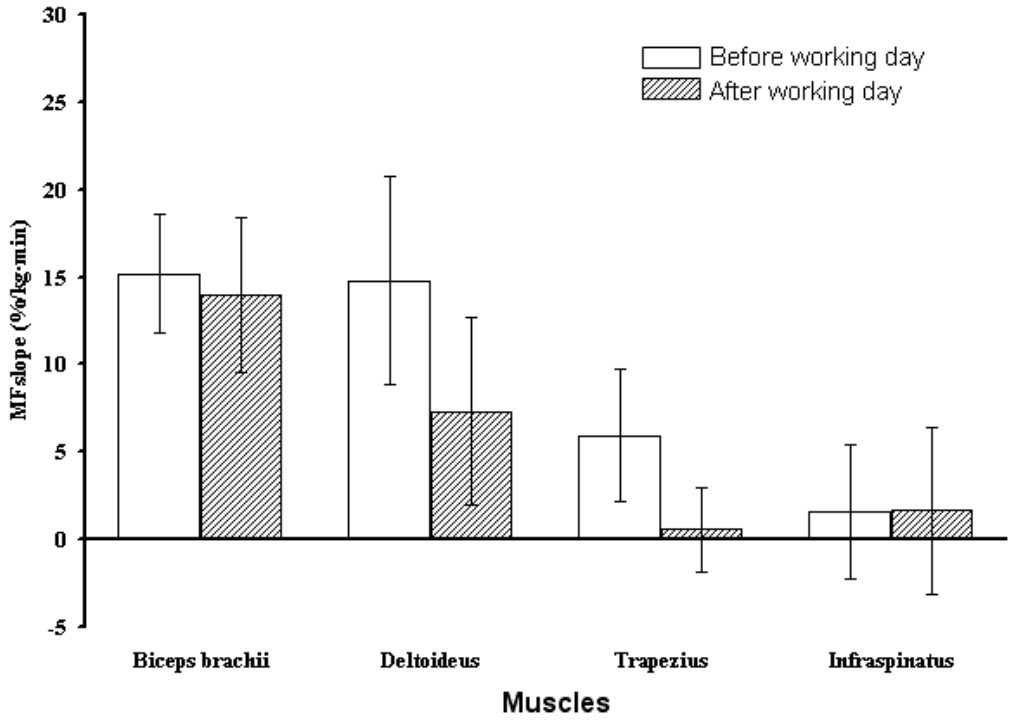

Fig. 3. The electromyogram power spectrum median frequency (MF) slope during a 3-minute wall painting test before and after the working day (mean ± SE).

The MF slope of the EMG power spectrum of the observed group revealed that in case of biceps brachii, deltoideus and trapezius, this indicator was moderately lower ($p>0.05$) at the end of the working day. But in case of infraspinatus MF slope it was moderately higher ($p>0.05$) at the beginning of the working day than it was at the end of the working day. This fact indicates that female painters tend to be more overloaded in the hands and shoulder region and less in the back.

The results indicated a significant subjective muscle fatigue sensation evaluated according to the Borg (CR-10) Scale in hands ($p<0.05$), lower limbs ($p<0.01$) and trunk ($p<0.05$) before and after working day (Fig. 4).

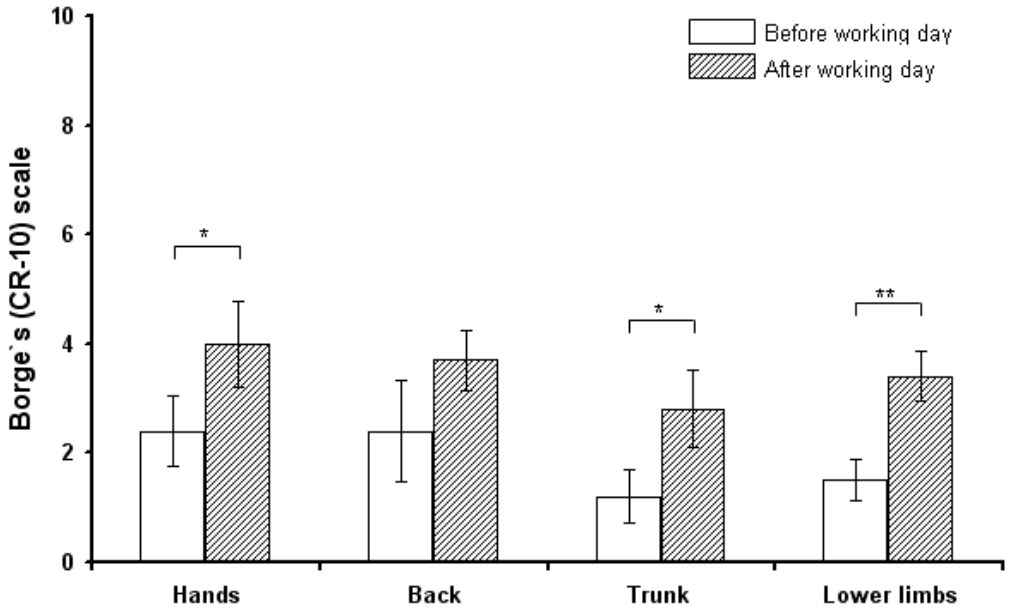

Fig. 4. Subjective muscle fatigue sensation estimated by the Borg Category Ratio (CR-10) Scale before and after the working day (mean ± SE). * $p<0.05$; **$p<0.01$.

A change in the subjective muscle fatigue sensation of hands, lower limbs and trunk before and after work was evident and this result deserves attention. It is known that physical stress and musculoskeletal discomfort while working can be alleviated and prevented by selecting the right tool that reduces the physical stress in the worker's fingers and hands to a minimum, and he or she needs to use less energy for working. A correctly selected tool also reduces jolting, repulse, and vibration (Marras & Karwowski, 2005).

The subjective muscle fatigue sensation of lower limbs may be due to the fact that painters have to stand throughout the working day mostly on concrete floor, which lacks amortization that would reduce jolting. Comfortable good quality working shoes are of great help for reducing such overload in case of workers (including painters), who have to work standing all day long. A pair of shoes which does not suit one's feet can cause problems lasting for years (Kane, 1987).

Proceeding from the data gained in the course of the research concerning the fact that the painters mostly had shoulder girdle and hands overload, it is recommended that they perform stretching exercises before and during the working day. A worker should customize the tools proceeding from his/her own anthropometrical measures and use suitable means of protection. This requires corresponding instructive materials and instructing the workers by a trained specialist. In case of physical work, it is advisable to make short breaks (5…10 minutes) every hour to avoid the problems caused by overload.

CONCLUSION

In conclusion, this study indicated that muscle fatigue, evaluated objectively by EMG power spectrum MF slope from biceps brachii, trapezius, deltoideus and infraspinatus muscles was not evident during a 3-minute wall colouring test before

and after the working day. However, subjective muscle fatigue sensation in female painters was higher after the working day in hands, lower limbs and trunk, less pronounced in the back.

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