Manifestations of muscle fatigue in the shoulders in light-assembly work

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The aim of this study was to determine how muscle fatigue develops in the upper trapezius muscle in a simulated assembly task at two different levels of low intensity. Ten subjects performed this task for three hours. EMG was recorded using bipolar electrodes on the left and right side. A significant decrease in EMG mean power frequency (MPF) over time was observed, while the signal amplitude did not increase significantly. Different patterns of the change in MPF were observed for the two intensity conditions.

Key-words: light-assembly work, muscle fatigue, electromyography

1 Introduction

Shoulder pain is a serious problem in the working population (Buckle and Devereux 2002). Elevated risks on shoulder pain are not only present in conditions of high internal loading forces (NRC and Institute of Medicine 2001). Repetitive manual assembly work is a clear example of 'light work' where risks of shoulder pain are elevated (Mathiassen et al. 1993).

Many hypothesize that shoulder muscle fatigue is a pain-initiating factor (Bjelle et al., 1981; Rempel et al., 1992; Takala, 2002). If so, muscle fatigue, when measured during work, would be a relevant biomarker for cumulative exposure to repetitive work. But does muscle fatigue really happen in work at low levels of about 10%MVC?

Several studies have been performed on the manifestation of muscle fatigue in light work conditions. Evidence on muscle fatigue development in low-level activity however, is mainly obtained in muscles of the extremities that are not habitually exposed to sustained activity. In studies on the shoulder muscle, trends indicating muscle fatigue based on EMG parameters were reported, but these were either not statistically tested or only partially significant (Suurküla and Hägg 1987; Mathiassen and Winkel 1996; Bosch et al. 2007). In none of these studies the intensity level was quantified, nor were the differences in fatigue development between different levels of low intensity addressed.

2 Objectives

We investigated the development of fatigue in the shoulder region during a three-hour repetitive assembly task at two low-intensity levels. Our research questions were: Can objective signs of fatigue be obtained from EMG recordings during a standardized three hours light assembly task and can differences between two different levels of low intensity work be detected?

3 Methods

3.1 Subjects and task

Ten healthy subjects performed a three-hour simulated assembly work task. The task consisted of constructing and taking apart a small tower of eight blocks with a cycle time of thirty seconds. Therefore, boxes with blocks were placed on the left and right side of the subject. Both hands were used in alternating order and one block was picked-up at the time. After completing a tower, subjects put it in a box in front of them.
In the 'very low intensity' condition (VL), the table height was individually adjusted so the elbow was flexed slightly more then 90° and the palms of the hands were just above the table. In the condition of 'low intensity' (L) the table height was increased by 10 cm, the box height of the parts was increased by 15 cm and the front boxes were placed 35 cm further away. The two conditions were performed in random order in two sessions on two consecutive days.

3.1.1 Measurements and analyses

EMG signals were recorded from the descending part of the upper trapezius muscle by using bipolar surface electrodes. A standard electrode location was defined as described by Hermens et al. (2000). The position of the electrodes was standardized using a strap with markers of the different locations. The electrode positions were marked with a waterproof pencil, in order to place the electrodes at the exact same position in both conditions. EMG signals were amplified 20 times (Porti- 17TM, TMS, Enschede, The Netherlands, input impedance >1012 Ώ, CMRR >90 dB), band-pass filtered (10–400 Hz) and A–D converted (22-bits) at a sample rate of 1000 Hz. EMG was recorded every other 2.5 minute (5 subsequent cycles*30 seconds = 1 trial) during the task performance. The mean amplitude was determined by averaging the band pass filtered (10-400Hz), rectified and normalized EMG signal over 5 cycles (2.5 min). The Mean Power Frequency (MPF) was calculated using a sliding window technique with a step size of 500 samples and a window size of 5000 samples. MPF values were calculated per window and averaged over one trial, resulting in one MPF value for each trial.
To study any manifestation of fatigue after 3 hours of light work, the amplitude and MPF values obtained at the start and end of both conditions were analyzed with a repeated-measures analysis of variance with independent variables time (2), condition (2) and side (2),
To study the temporal changes in the EMG parameters, a second order regression line was fitted through all thirty-six MPF and mean amplitude samples for the standard electrode locations. The coefficients and intercept of the regression equations were analyzed using another repeated-measures ANOVA with the independent variables condition (2) and side (2).

4 Results

As intended the amplitude differed significantly between the conditions (p=0.001). The initial amplitude was 8.6 (5.1) in the VL and 12.5 (5.2) %MVC in the L-condition.
The so-called JASA plots in figure 1 show that over a period of three hours most of the participants show a combination of an increase of the EMG amplitude and a decrease of the MPF.
Our statistical analysis of start and end data points, showed significantly lower MPF values at the end of the three-hours task (p=0.001). The significant interaction between time and condition for the task, showed that this decrease was larger for the L-condition

compared to the VL condition (p=0.013). No significant start vs. end differences were observed for the amplitude values.
The statistical analysis of the coefficients of the regression line fitted through the individual data series showed that the MPF changed significantly over time. The linear coefficient (p=0.027) as well as the quadratic coefficient (p=0.02) were lower for the L-condition than for the VL-condition. In contrast, the amplitude was not found to change significantly.

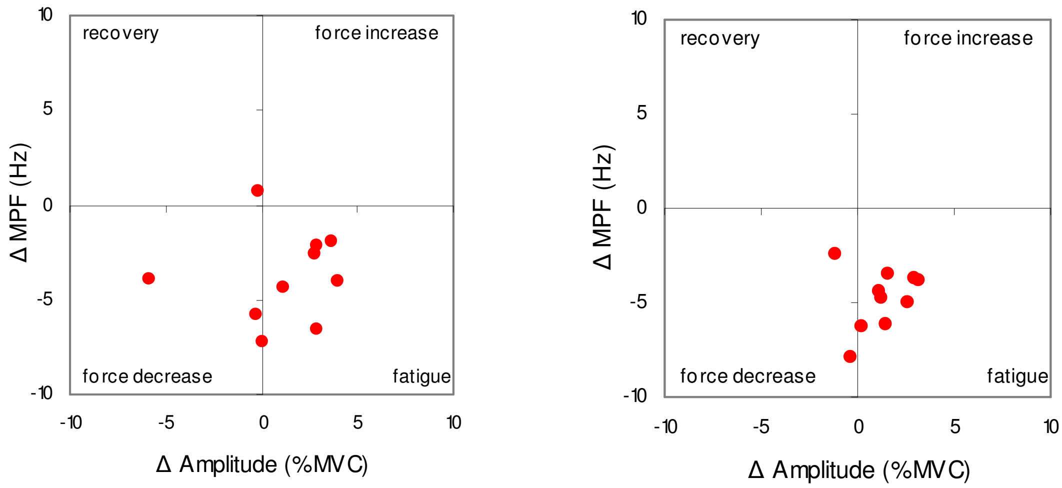

Figure 1: Two dimensional JASA plots of 10 subjects in condition VL (left) and condition L (right) for the amplitude and MPF changes. The differences between the MPF and amplitude values at the start (t1) and end (t36 or t12) were estimated using the second order regression equations.

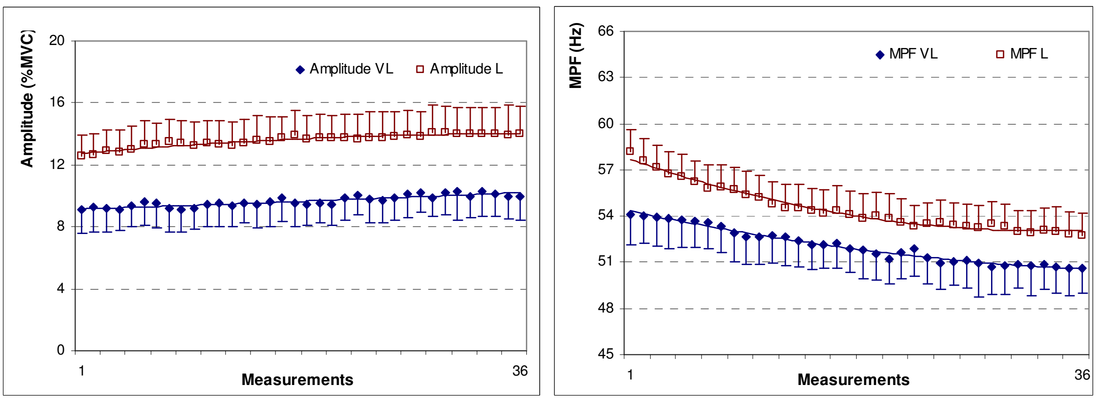

Figure 2: Change in amplitude and MPF across 36 measurements (3 hours). The values are averaged over 10 subjects and error bars indicate the standard error.

5 Discussion

The JASA plots showed that over a period of three hours most of the participants showed a combination of an increase of the EMG amplitude and a decrease of the MPF. The combination of these changes has been interpreted as a manifestation of muscle fatigue. At the group level, the statistical analysis showed only a significant decrease of the MPF in both conditions. This decrease was larger in the low intensity condition compared to the very low-intensity condition.

The changes in the frequency content have usually been explained as stemming from changes in conduction velocities and from synchronisation of active motor units (e.g. Fallentin et al., 1993). The increase of EMG amplitude has usually been explained by additional motor unit recruitment (Maton and Gamet, 1989). In this study the additional recruitment of MU's might have been compensated by a reduction of required forces as a consequence of improved working technique.

We also studied the detailed temporal development of electromyographical changes by including more measurements. The decrease of the MPF showed a different pattern between conditions. In the low intensity condition the MPF showed a non-linear decrease while the very low condition showed a more linear decrease (see figure 2b) Consistent with our results in the L-condition, Krogh-Lund and Jensen (1985) showed that during an intermittent isometric contraction (20 %MVC) the most rapid changes took place over the first 2-3 hours of work.

This study showed some manifestation of fatigue as well as significant differences in fatigue development between two low-level conditions. MPF results were significant, but amplitude results were not in this relatively small sample. Possibly the use of multiple surface electrode pairs on the muscle will further increase the sensitivity of fatigue assessments by allowing estimates of muscle fiber conduction velocity.

6 References

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