Muscle activity and fatigue in the shoulder muscles during repetitive work

An electromyographic study

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Summary. The amplitude distribution probability function (ADPF) and the power spectrum of the surface electromyogram from m. deltoideus anterior, m. infraspinatus and m. trapezius pars descendens were analyzed from 7 persons working at a pillar drill. Recordings were performed 6 times during a working day. The ADPF was analyzed from 2—3 work-cycles from each recording. The static contraction level was 11.0% MCV in m. deltoideus anterior, 8.5% MVC in m. infraspinatus, and 20.5% MCV in m. trapezius, without any change occurring throughout the day. When compared to previous suggested upper limits of ADPF levels, both the static and the medium contraction levels were too high in the performance of this particular task. The power spectrum of the EMG was analyzed during isometric contractions of the shoulder muscles. The mean power frequency decreased during the day in m. trapezius only, suggesting muscular fatigue in this area.

Key words: Fatigue — Monotonous work — EMG — Power spectrum — Amplitude distribution

Introduction

Development and mechanization of industrial work processes have simplified the movements involved, but at the same time have increased the number of movements per unit time. In general these simple movements are less energy demanding, but the velocity and monotony represent a local stress on the skeletal muscles (Jonsson 1982).

One of the side effects of this mechanization seems to be an increased incidence of pain in the locomotor system, in particular for employees in light industrial work, workers at assembly lines and others for whom the working processes are characterized by simple and light repetitive movements. The symptoms are most frequently found in the back, neck, shoulders and upper arms (Kvarnström 1983; Luopajärvi et al. 1979; Onishi et al. 1976).

Electromyographic (EMG) recordings permit analysis of the degree of activity in skeletal muscle. The relationship between the amplitude of the EMG and force developed during muscle contraction, is found to be either linear (Bigland and Lippold 1954; Christensen et al. 1984; Komi 1973) or exponential, with a greater increase occurring in the amplitude than in force (Antti 1977; Komi and Buskirk 1970; Lawrence and DeLuca 1983).

An increased amplitude (Edwards and Lippold 1956) and a shift of the energy content towards lower frequencies (Kadefors et al. 1968; Kwatny et al. 1970) is seen in the EMG when a muscle sustains an isometric contraction, as demonstrated in laboratory (Petrofsky et al. 1982) and workshop experiments (Herberts et al. 1980; Kahabka 1984).

The purpose of the present investigation was to evaluate the degree of muscle activity and muscle fatigue in shoulder muscles during a whole working day, in workers performing monotonous and repetitive work. Muscle activity and fatigue were estimated from the distribution of amplitudes and the mean power frequency of the power spectrum of the electromyogram.
Subjects and methods

Subjects. Seven male subjects aged 26-53 years took part in the experiments after their informed consent was obtained. Mean height was 173.6 cm (range 168-182 cm) (Table 1). All subjects were day-patients at a rehabilitation and revalidation institute. The reasons for their being at this institute were fractures of the lower extremities (4 subjects) or social factors (3 subjects). At the time of the study, the condition of the locomotor system of each subject was regarded as normal, judged from a clinical investigation, a test of cardiovascular function on a bicycle ergometer and a test of the maximal isometric muscle strength of several muscle groups. All subjects, when tested, were about to be discharged from the institute.

Electromyographic activity was recorded while subjects worked at a pillar drill (Fig. 1). All subjects became accustomed to the work process during a two week training period before the experiment.

The work process. Work at the pillar drill was performed with the subject in a sitting or standing position (Fig. 1). The work consisted of drilling holes in small metal components. The metal components were taken by the left hand from a box to the left of the machine and were then placed under the drill. The handle of the drill was pressed down with the right hand. The right hand then removed the component once the hole had been drilled. The whole cycle lasted an average of 25 s.

Electromyography. The electromyographic activity was sampled using bipolar surface electrodes, with a leading-off area of 25 mm² (Medicotest-A-10-VS). Recording electrodes were placed on the right side of m. trapezius (pars descendens), m. deltoideus (pars anterior) and m. infraspinatus (Fig. 2). The distance between the electrodes was 2 cm and the inter electrode resistance was below 20 kΩ.

The signals were transmitted telemetrically via small portable units (5 cm x 5 cm x 11 cm, Medinik IC-600-C). The 3 transmitter units were carried in a belt placed around the waist. The signals were amplified 1000 times, and stored on a tape recorder (Briel & Kjaer 7005). The quality of the signals was controlled on an oscilloscope (LEADER Dual Trace LBO-308S). Power was provided by a 12-Volt accumulator. The quality of the signals was controlled and later evaluated from a print-out (Mingograf 800).

Muscle strength. Maximal voluntary contraction force (MVC) of the three muscles examined was measured using a strain-gauge dynamometer (Asmussen et al. 1959). The maximal strength of m. deltoideus was tested with the subject in a standing position. M. infraspinatus and m. trapezius were tested with the subject in a supine position (Fig. 3). Each muscle was tested for its maximal strength at least 3 times.

Heart frequency. Heart beats per minute were recorded from chest electrodes and stored in a portable Memolog 500 (11 cm x 6.5 cm x 3.5; 360 gr) (NOVO Electronics).

All recordings were analyzed on a Memoscan 510 (NOVO Electronics). Results were presented on a print-out as mean, 1 SD, highest and lowest values, as well as on an x-y plot as beats per minute per time unit.

Rate of perceived exertion. Immediately following each recording, the subject reported the rate of perceived exertion (RPE) in the shoulder according to a 9-grade scale (Borg 1982).

Efficiency. Efficiency of the work, expressed as the number of elements handled per unit time, was calculated for each recording.

Procedure. The subject arrived 45 min before the start of a normal working day. The subjects were asked to arrive by car or by bus to avoid physical efforts. Electrodes were carefully mounted, and maximal strength was measured. In order to obtain calibration curves, EMG and force were recorded during a gradually increasing voluntary contraction.

<table>
<thead>
<tr>
<th>Age years</th>
<th>Height cm</th>
<th>Shoulder flexion (m. deltoideus) N</th>
<th>Shoulder rotation (m. infraspinatus) N</th>
<th>Shoulder lifting (m. trapezius) N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>40.6</td>
<td>173.6</td>
<td>139.8</td>
<td>141.6</td>
</tr>
<tr>
<td>1 SD</td>
<td>9.0</td>
<td>5.3</td>
<td>53.0</td>
<td>22.0</td>
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<tr>
<td>Range</td>
<td>(26-53)</td>
<td>(168-182)</td>
<td>(73.5-221.9)</td>
<td>(108.4-163.2)</td>
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