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TRAPEZIUS MUSCLE PRESSURE PAIN THRESHOLD AND STRAIN IN THE NECK AND SHOULDER REGIONS DURING REPETITIVE LIGHT WORK

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ABSTRACT. Perceived musculoskeletal discomfort caused by the repetition of a light work task was examined by rating the perceived musculoskeletal discomfort and measuring the muscle pressure pain threshold. Thirteen healthy female workers performed a repetitive light work task for 120 minutes. Based on the perceived musculoskeletal discomfort during the work task the subjects were assigned to one of two groups, i.e., those who reported most complaints and those who reported fewest complaints. The pressure pain thresholds of the trapezius muscles in the most-complaining group were significantly lower than those in the least-complaining group. The pressure pain threshold was logarithmically correlated both with the perceived musculoskeletal discomfort and with the EMG signal amplitudes.

Key words: perceived musculoskeletal discomfort, repetitive work, pressure pain threshold, electromyography, neck and shoulder muscles.

In patients suffering from chronic musculoskeletal disorders, the pain originates from muscles, tendons, ligaments, and certain other neighbouring structures. In many cases, pain is localized to small circumscribed areas that are very tender on palpation and extremely sensitive to pressure (2). Muscle tenderness is, therefore, considered to be a sign which may precede musculoskeletal disorders (17, 19). Palpation is recognized as the most sensitive method for diagnosing pain and identifying its source (2). In this context, muscle tenderness and tenderness of the spinous processes have been used as diagnostic criteria for occupational cervicobrachial disorders (7).

In order to express muscle tenderness quantitatively it is essential to measure the pressure pain threshold. Measurement of pressure pain threshold has been performed both in clinical surveys (4, 5, 6, 13, 14, 18) and in surveys on various working populations (8, 11, 12, 15, 16). Sensations of discomfort such as stiffness and local fatigue are commonly experienced in daily life. It is also common that musculoskeletal disorders evolve from a slight sensation of discomfort into severe pain. The sensation of discomfort may be one of the expressions of a very early stage of chronic musculoskeletal disorders (7).

Observation of the changes in muscle pressure pain threshold and perceived musculoskeletal discomfort during work situations in healthy subjects may help us understand how occupational musculoskeletal problems develop.

The present study is part of a programme to investigate various physiological effects related to repetitive work. In a previous study (9) it was shown that healthy subjects performing a repetitive work task could be subdivided into a "most-complaining group" and a "least-complaining group" based on their perceived musculoskeletal discomfort in different body regions during work (for a definition, see Methods). It was shown that the perceived musculoskeletal discomfort in various body regions increased linearly during the repetitive light work task.

The aim of the present study was to find answers to the following questions:

1. Are there any differences in the number of tender muscles and tender spinous processes between most-complaining and least-complaining subjects?
2. Are there, during repetitive light work, any differences in trapezius muscle pressure pain threshold between most-complaining and least-complaining subjects?
3. Is there, during repetitive light work, any correlation between the levels of trapezius muscle pressure pain threshold and perceived musculoskeletal discomfort in the neck and shoulders of the subjects?

4. Is there, during repetitive light work, any correlation between the levels of trapezius muscle pressure pain threshold and the myoelectric signal amplitudes in the trapezius muscles of the subjects?

MATERIALS AND METHODS

Subjects

Thirteen young subjectively healthy working females with a mean age of 26 years (range 19–32) volunteered to participate in the study. Ten of them worked as professional cleaners, and the remaining three comprised a laboratory assistant, a dental hygienist, and a secretary. The subjects were thoroughly informed about the experimental procedure before joining the study. Their mean height was 1.63 m (range 1.49–1.73), and mean body weight was 58 kg (range 46–70). All subjects were right handed.

At the start of the experimental procedure all the subjects were subjected to a physical examination that focused on musculoskeletal complaints. None of the subjects revealed any signs of musculoskeletal disorders.

Experimental procedure and work task

The first 3 hours of the experiment were used for physical examination, application of electrodes for electromyography (EMG), and measurement of maximal reference voluntary contractions. After a one-hour lunch break, the subjects performed a repetitive light work task for 2 hours, followed by a 40-min rest period. The pressure pain threshold of the trapezius muscles and the perceived musculoskeletal discomfort in different body regions were examined on seven occasions during the experiment; i.e., before starting the preparations of the subject, after the preparations of the subject, after the lunch break before starting the work task, after 40, 80, and 120 min of repetitive light work, and after 40 min of rest.

The subjects were asked to perform a repetitive light work task for a total of 120 min, simulating tasks that occur, for example, on assembly lines in electronics factories. The work task has been described previously (9). The task was to insert small nails and screws into holes in metal boards. The work task was repeated over and over again, continuously for 2 hours without pauses. The work task was performed with the boards placed on a table and with the subject seated on an ergonomically well-designed office chair in an ergonomically appropriate posture. The subjects were allowed to choose the working pace that they would consider suitable if they had to continue the work task as a full-time worker for 8 hours a day. They were also free to chat with the experimenters while performing the work task. All the subjects were well instructed and given a few boards to practice on before starting the experiment. The work task was documented with video recordings for observation of working rhythm, e.g., time per board, and productivity (number of boards handled). All subjects kept working in their own working rhythms during 2 hours, and there were no significant changes in working rhythms in any of the subjects during the 2 hours of work.

Evaluation of perceived musculoskeletal discomfort

During the experiment the subjects were asked to evaluate their current perceived musculoskeletal discomfort bilaterally in seven body regions (the neck, shoulder, upper arm, forearm, wrist/hand, upper back, and low back). In the present study, sensations of stiffness, pain, and local fatigue were defined as "perceived musculoskeletal discomfort". Borg's category ratio scale (CR-10 scale) was used to measure perceived musculoskeletal discomfort (1).

Based on the perceived musculoskeletal discomfort during the work task the subjects were divided into a "most-complaining group" and a "least-complaining group". The "most-complaining group" consisted of those 7 subjects, for whom the mean rating of discomfort in all the 14 examined body regions on at least one occasion exceeded the value of 1.0 on Borg's scale (very weak discomfort). The "least-complaining group" consisted of those 6 subjects for whom the mean rating of discomfort in all the 14 examined body regions on no occasion exceeded the value of 1.0 (9). There was no significant difference between the two subgroups in productivity during the work task.

Evaluation of muscle tenderness and tenderness of spinous processes

The physical examination of the subjects included palpation of 25 different muscles/tendons bilaterally (Fig. 1) and examination of the tenderness of spinous processes. Every palpation site of the muscles/tendons and their attachments to the bones were carefully examined. Tenderness of spinous processes, from the C5 down to the L5 spinous processes, were examined by placing the tip of the examiner's thumb on each spinous process and pressing perpendicularly against it. The number of tender muscles and the number of tender spinous processes were counted for each subject.

Measurement of pressure pain threshold

The pressure pain threshold of the descending part of the trapezius muscles was measured bilaterally by a small strain-gauge sensor, manufactured by Shigehru industry, Japan. The pressure could be measured from zero up to 40 N/cm^2 with 1 N/cm^2 divisions.

The round-tipped metal bar of the strain-gauge sensor with a skin-contact surface area of 1 cm^2 was placed perpendicularly over the descending part of the trapezius muscle close to its upper border and in the middle between the origin and the insertion. The tip of the sensor was then gradually pressed against the muscle with slowly increasing force until the subject reported that she felt pain. The subject was asked to say "now" at the moment when the pressing sensation turned into pain. Then the compression was stopped and the scale was read. On each occasion the measurement of pressure pain threshold was repeated five times. The highest and the lowest values were disregarded, and the mean value of the pressure pain threshold was calculated from the remaining three readings.

The data for the pressure pain thresholds in the trapezius muscles and the simultaneously recorded average ratings of perceived musculoskeletal discomfort in the neck, shoulder and upper back regions were compared and their correlation was examined.

Electromyography (EMG) and reference voluntary contraction

The electromyographic procedure has been described in a previous study (9). Electromyographic (EMG) activity was recorded bilaterally from the descending part of the right and

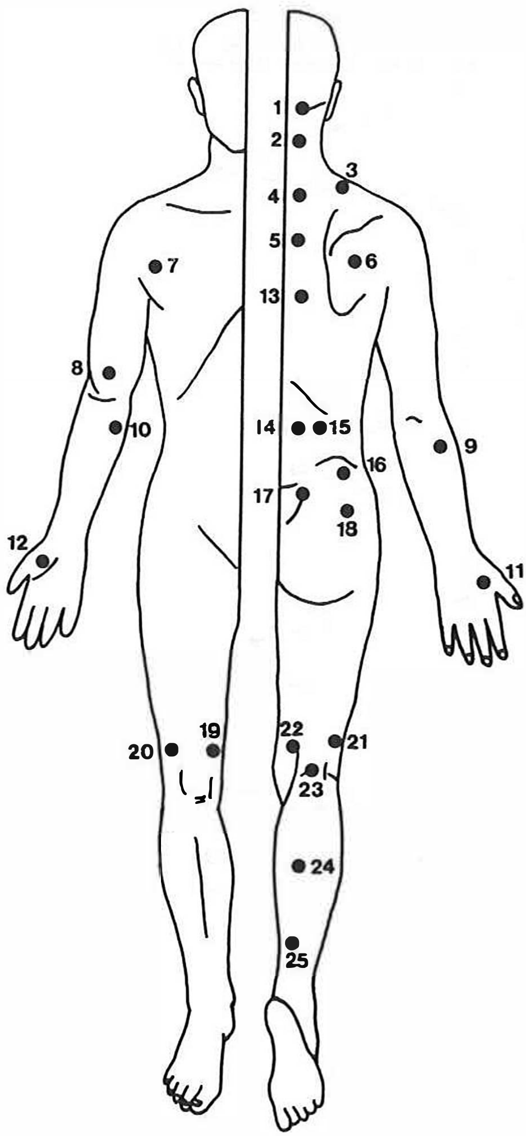

Fig. 1. Location of palpated muscles/tendons examined bilaterally in 25 different locations: 1: Linea nuchae superior, 2: Erector spinae (cervical), 3: Trapezius, 4: Rhomboideus minor, 5: Rhomboideus major, 6: Infraspinatus, 7: Pectoralis major, 8: Biceps brachii, 9: Extensors of forearm, 10: Flexors of forearm, 11: First dorsal interosseous, 12: Thenar, 13: Erector spinae (thoracic): 14: Erector spinae (lumbar), 15: Quadratus lumborum, 16: Gluteus medius, 17: Posterior sacroiliac ligament, 18: Gluteus maximus, 19: Vastus medialis, 20: Vastus lateralis, 21: Biceps femoris, 22: Semimembranosus/semitendinosus, 23: Popliteal fossa, 24: Gastrocnemius, 25: Tendo calcaneus.

left trapezius muscles. Bipolar silver-silver chloride surface electrodes were used.

The EMG signals were amplified with a band width of 10 to 1,500 Hz by small telemetric amplifiers. The signals were monitored on an oscilloscope and on paper with an ink recorder, for signal control and for detection of artifacts. The electromyographic signals were recorded by an FM tape recorder (band width DC to 2500 Hz).

EMG signals were also recorded during a series of well defined maximal reference voluntary isometric test contractions (9). Each test was repeated three times. Regardless of the type of test contraction, the highest EMG signal amplitude level for each individual muscle was used as the maximal EMG value. The EMG signal amplitudes recorded during the work task was then normalized to this maximal value (%RVC).

For analysis the EMG signals were root mean squares detected with a time constant of 100 ms. The EMG signals recorded during the 120 min of work were divided into six 20-min records and the average EMG signal amplitude level (%RVC) was calculated for each 20-min record. The pressure pain thresholds of the right and left trapezius muscles after 40, 80, and 120 min spent on the work task were correlated with the average EMG signal amplitude levels in the trapezius muscles recorded during the 20 min of work preceding each pressure pain threshold measurement.

Statistics

The Mann-Whitney U test was used to test differences in the results between the two subgroups. The Wilcoxon signed rank test was used to test the differences in the results within the subgroups. The Spearman rank correlation coefficient was calculated to test the correlation between the number of tender muscles/tendons and the perceived musculoskeletal discomfort. Regression analysis was used to test the best fitting curves for the relations between the pressure pain threshold and the perceived musculoskeletal discomfort, and between the pressure pain threshold and the EMG signal amplitude levels. Average values for the pressure pain threshold, the EMG signal amplitude and the perceived musculoskeletal discomfort were used for the regression analysis. The statistical tests were performed at the 5% significance level ($p < 0.05$, two-tailed).

RESULTS

Muscle tenderness and tenderness of spinous processes

For the 25 muscles/tendons examined bilaterally the median number of tender muscles/tendons among the 13 subjects was 8.0 (range: 0–42). The highest tenderness rate occurred in the right and left trapezius muscle, as well as in the lumbar region (Fig. 2). The most-complaining group revealed higher tenderness rates than the least-complaining group in almost all of the muscles/tendons examined. The median number of tender muscles/tendons in the least-complaining group and in the most-complaining group were 3.5 (range: 0–20) and 13.0 (range: 3–42), respectively. The number of tender muscles/tendons in the most-complaining group was fairly higher than that in the least-complaining group ($p = 0.053$). Rank order correlation between the number of tender muscles/tendons

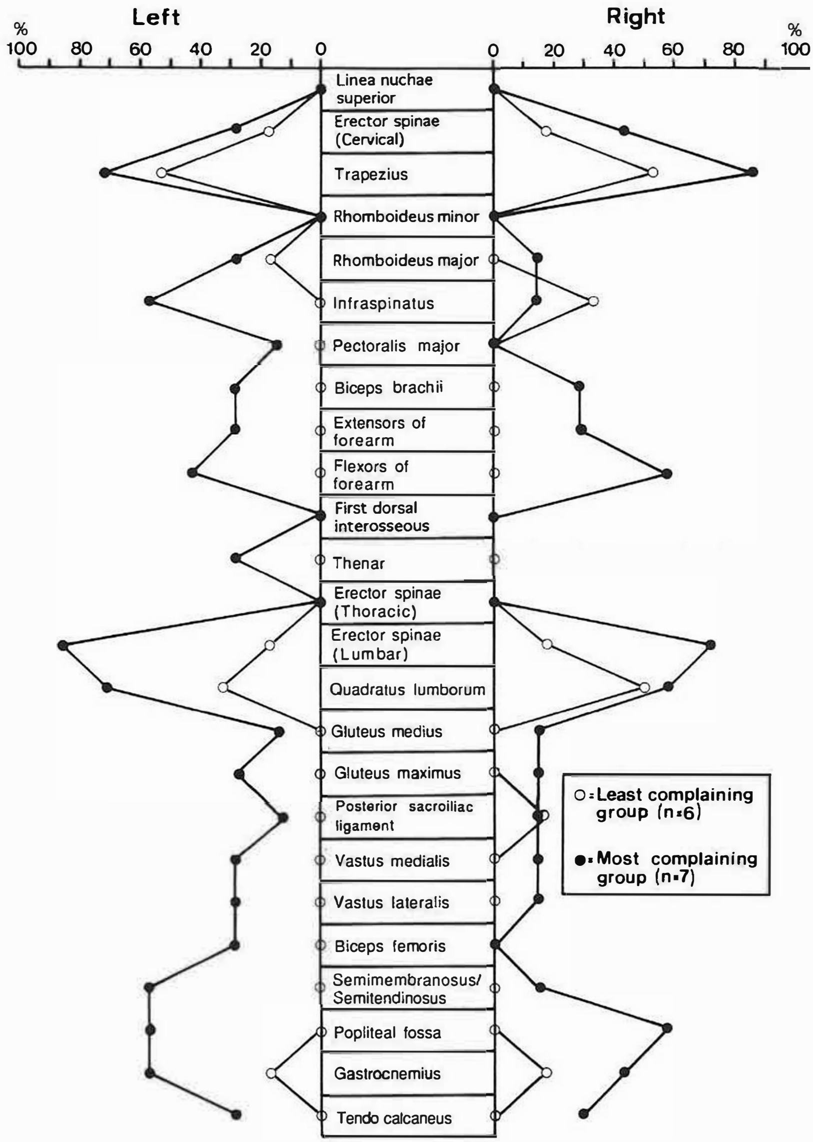

Fig. 2. Percentage of subjects with tender muscles/tendons examined bilaterally in 25 different locations.

and the mean of perceived musculoskeletal discomfort during the work task was 0.67 ($p = 0.013$).

The number of subjects revealing tender spinous processes on palpation was rather low, one subject in the least-complaining group (5 tender spinous processes) and 3 subjects in the most-complaining group (1, 2 and 5 tender spinous processes, respectively).

Pressure pain threshold of the trapezius muscles

In the least-complaining group the initial pressure pain threshold values were significantly higher than those in the most-complaining group ($p = 0.022$ for the right side, $p = 0.032$ for the left side) (Fig. 3). During the preparations, the pressure pain threshold in the least-complaining group showed a tendency to decrease (significantly on the right side, $p = 0.028$). The pressure pain threshold level showed a tendency (non significant) to increase during the lunch break. At the beginning of the work task the pressure pain threshold level of the least-complaining group was significantly higher on the left side ($p = 0.032$) compared to that of

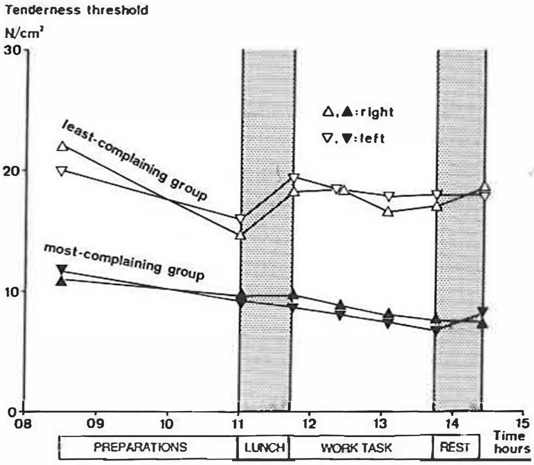

Fig. 3. Pressure pain threshold of the right and left trapezius muscles in the two subgroups during the whole experimental procedure.

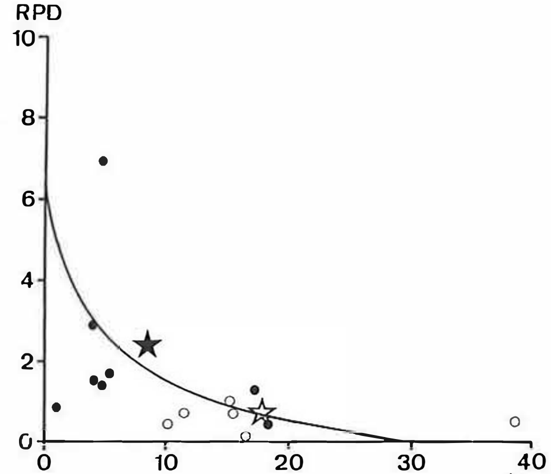

Fig. 4. Relationship between mean pressure pain threshold of the right trapezius muscle and corresponding mean ratings of perceived musculoskeletal discomfort (RPD) in the right neck, shoulder, and upper back regions. $Y = 4.8 - 1.4 \ln X$ ($r = 0.56$; $p = 0.047$). ○: least-complaining group ($n = 6$), ☆: mean value of the least-complaining group, ●: Most-complaining group ($n = 7$), ★: mean value of the most-complaining group.

the most-complaining group. At the end of the 2-hour work task, the difference in the pressure pain threshold level between the two subgroups was significant ($p = 0.043$ for the right side, $p = 0.031$ for the left side). Neither in the least-complaining group nor in the most-complaining group were there any significant changes in pressure pain threshold from the start of the experiment to the end of the repetitive light work.

Relationship between pressure pain threshold and perceived musculoskeletal discomfort

The mean values of the four measurements (i.e., at 0, 40, 80, and 120 min during the work task) of the pressure pain threshold and the perceived musculoskeletal discomfort revealed that the relationship (Fig. 4) was best described with a logarithmic regression curve ($r = -0.56$; $p = 0.047$ for the right side, $r = -0.52$; $p = 0.068$ for the left side). That means that the ratings of perceived musculoskeletal discomfort in the neck, shoulder, and upper back regions during the 2 hours of work showed a negative correlation with the pressure pain threshold levels in the trapezius muscles.

Relationship between pressure pain threshold and EMG signal amplitude

In the least-complaining group the EMG signal amplitude levels in the trapezius muscles increased during the work task, while in the most-complaining group there was no change (9). The EMG signal amplitude levels in the trapezius muscle showed a positive correlation with the pressure pain threshold levels. The mean values for the pressure pain threshold and the mean values for the EMG signal amplitude revealed that the relationship (Fig. 5) was best described with a logarithmic regression curve ($r = 0.62$; $p = 0.023$ in the right trapezius muscle, $r = 0.62$; $p = 0.025$ in the left trapezius muscle). As a result, the subjects in the least-complaining group, who had higher pressure pain threshold levels, showed higher EMG signal amplitude levels than those of the most-complaining group, who had lower pressure pain threshold levels.

DISCUSSION

In a previous study of the same group of subjects it was shown that they could be divided into a least-complaining group and a most-complaining group based on their perceived musculoskeletal discomfort in various body regions during light repetitive work (9). In the present study, a significant difference in the number of tender muscles/tendons was found between the most-complaining group and the least-complaining group. There was no difference in the number of tender spinous processes between the two subgroups.

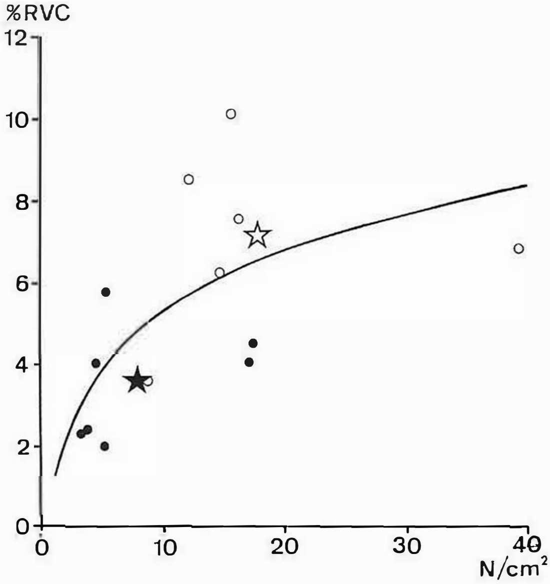

Fig. 5. Relationship between mean pressure pain threshold of the right trapezius muscle and corresponding mean EMG signal amplitudes expressed in %RVC. $Y = 0.4 + 2.1 \ln X$ ($r = 0.62$; $p = 0.023$). ○: least-complaining group ($n = 6$), ☆: mean value of the least-complaining group, ●: most-complaining group ($n = 7$), ★: mean value of the most-complaining group.

The rank orders of the number of tender muscles/tendons and the mean of perceived musculoskeletal discomfort correlated rather well. The existence of tender muscles/tendons might play an important role in the development of perceived musculoskeletal discomfort during repetitive light work.

In order to measure muscle tenderness quantitatively it has proved useful to measure the muscle pressure pain threshold (3, 4, 6, 13). In the present study it was found that there was a significant difference in the pressure pain threshold levels of the trapezius muscle between the least-complaining group and the most-complaining group. The difference between the two subgroups was significant throughout almost the entire experimental procedure. The pressure pain threshold levels of the least-complaining group tended to be influenced by the experimental procedures during preparations and by the break during lunch. A similar phenomenon has been observed in a study of the pressure pain threshold in the trapezius muscle of female keyboard operators (12), i.e., during work the pressure pain threshold decreased from morning till the end of the work day and from Monday to Friday. The pressure pain threshold level also increased during the lunch break in their study. However, the authors did not describe any inter-individual differences with respect to perceived musculoskeletal discomfort. The effect of repetitive measurements of pressure pain threshold is unknown. In the present study there were no significant differences in the pressure pain threshold levels between the start of the experiment and the end of the experiment be it in the least-complaining group or in the most-complaining group. Thus, the 35 measurements performed during the present experiment obviously did not influence the pressure pain threshold level in the two subgroups.

There was a negative correlation between the perceived musculoskeletal discomfort in the neck, shoulder and upper-back regions and the pressure pain threshold levels in the trapezius muscles. The subjects in the least-complaining group showed lower perceived musculoskeletal discomfort levels and higher pressure pain threshold levels, while the subjects of the most complaining group showed higher perceived musculoskeletal discomfort levels and lower pressure pain threshold levels during the work task. Tunks et al. (18) reported that pressure pain threshold levels of tender points in fibromyalgia patients are significantly lower than in normal subjects. Workers suffering from musculoskeletal problems have revealed significantly lower pressure pain thresholds than workers without problems (8, 11). Pressure pain threshold may also be influenced by psychosocial factors such as working conditions (10).

In the previous study on the same group of subjects it was shown that the EMG amplitude levels increased significantly without any distinct signs of muscular fatigue during light repetitive work (9). In the present study it was shown that there was a positive correlation between the EMG amplitude levels and the pressure pain threshold levels during the work task. The subjects in the least-complaining group showed higher EMG amplitude levels and higher pressure pain threshold levels, while the subjects in the most-complaining group showed lower EMG amplitude levels and lower pressure pain threshold levels during the work task. Öberg et al. (20) examined patients with unilateral trapezius myalgia by exposing them to static muscle load. They found an increase in EMG signal amplitudes and a decrease in mean power frequencies on both sides. However, the change was smaller on the affected side than on the non-affected side. They attributed this to pain inhibition, impaired circulation, and biochemical changes. The discrepancy in EMG signals between the most-complaining group and the least-complaining group in the present study may be explained in a similar way.

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