Low-amplitude trapezius activity in work and leisure and the relation to shoulder and neck pain

Paul Jarle Mork and Rolf H. Westgaard
Norwegian University of Science and Technology, Trondheim, Norway
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Mork, Paul Jarle, and Rolf H. Westgaard. Low-amplitude trapezius activity in work and leisure and the relation to shoulder and neck pain. J Appl Physiol 100: 1142–1149, 2006. First published December 1, 2005; doi:10.1152/japplphysiol.01111.2005.—The aim of this study is to obtain evidence supporting or negating the hypothesis that muscle pain is associated with sustained activation of low-threshold motor units. Long-term surface electromyographic (EMG) recordings of trapezius activity pattern were related to subjectively reported shoulder and neck pain in work and leisure. Recordings from 118 female subjects (73 recorded both during work and leisure) were analyzed. Computer operators, secretaries, and health care and retail workers were represented in the material. The recordings were calibrated by the root-mean-square-detected response at maximal voluntary contraction (%maximum EMG). The analysis was performed by quantifying duration and amplitude of surface EMG activity exceeding 2% maximum EMG (“EMG bursts”). Three response categories were defined by duration of the burst periods during work: low- (<50%), intermediate-(50–70%), and high-response (>70%) groups. Shoulder and neck pain was assessed by hourly visual analog score throughout work and leisure and by pain score for the last 6 mo. Shoulder and neck pain was higher at work than leisure for subjects with long-term pain in both the high- and the low-response groups. Persistent pain, defined by the 6 mo score, was more prevalent in the high- than the low- and intermediate-response groups (73 vs. 37%); relative risk was 2.0. Trapezius activity was reduced from work to leisure for the high- but not the low-response group. The activity pattern is consistent with low-threshold motor unit overexertion for the high- but not the low-response group. We speculate that different mechanisms of muscle pain causation, dependent and independent of motor activity pattern, coexist.

OVEREXERTION OF LOW-THRESHOLD motor units (7) is a possible model to explain pain development at low muscle activity levels (e.g., Refs. 29, 36). According to the Henneman size principle (9), motor units are recruited in fixed order, and, consequently, low-threshold motor units may sustain long periods of firing, even at low muscle activity. Enlarged cross-sectional area and reduced capillary-to-fiber ratio of type I fibers as well as mitochondrial disturbances (i.e., ragged red and cytochrome-c oxidase negative fibers; Refs. 21, 26) are phenomena that may be related to muscle fiber overuse; however, there is no clear evidence that these morphological findings are associated with shoulder and neck pain (6, 23, 24).

Other studies have shown shoulder and neck pain associated with phenomena unrelated to trapezius surface electromyographic (sEMG) activity, e.g., localized EMG responses in pressure-sensitive, pain-releasing trigger points (34, 35). Such responses are enhanced in patients with pain syndromes (3, 13) and were triggered by imposed stress in a laboratory study (28). Thus physiological processes associated with pain in the shoulder and neck may take place without being detected by sEMG recording.

Long-term sEMG recordings from the upper trapezius muscle (including work and leisure periods) of subjects with moderate demands of physical exertion have been carried out over several years in this laboratory (11, 31, 47). In the present study, this material is used to examine whether there is an association between trapezius activity pattern and pain in the shoulder and neck region. We further examine whether there are similarities in trapezius activity pattern during work and leisure. If so, this represents additional evidence in support of idiosyncratic activity patterns (“postural motor habits”; Ref. 31). The analysis of sEMG recordings is based on burst analysis (22), whereby periods exceeding 2% of sEMG activity at maximal voluntary contraction (MVC) (2% EMGmax) are characterized. This analysis strategy is preferred as burst time provides an indication of the duration of active periods for motor units with the lowest thresholds. The duration of periods with active muscle usage (burst time) is expected to differ from work to leisure, whereas periods with active use of the trapezius may show similar characteristics (i.e., similar burst amplitude). Furthermore, periods of “muscle rest” (<0.5% EMGmax) are quantified, representing periods with fewer than two to three trapezius motor units firing underneath the surface electrode (42).

The main aim of this study is to examine trapezius recordings of subjects with low biomechanical loading for associations between trapezius activity pattern and shoulder and neck pain. The hypothesis, also formulated in previous publications (38, 43), is that sustained low-level trapezius activity is related to shoulder and neck pain but that such pain also can occur independently of trapezius activity. Subjects were divided into three groups with low, intermediate, and high trapezius activity, based on sEMG responses during work. The groups were compared with respect to pain intensity in work and leisure and prevalence of long-term pain. A second aim is to compare trapezius activity patterns in work and leisure to test the hypothesis of stable intrasubject and variable intersubject motor patterns during periods of active muscle usage.

MATERIALS AND METHODS

Subjects. This study is based on new analyses of data collected in earlier studies. Table 1 presents an overview of the material, including listing of publications with the first presentation of sEMG recorded.

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material. Some subjects employed in health care and retail were recorded twice, with the first recording covering only the work period, but a full 24-h recording the second time. For these subjects, the second recording is included, supplemented by subjects with only work recording when the relation between trapezius activity pattern during work and long-term pain is examined. Subjects set up for 24-h work recording when the relation between trapezius activity pattern during work and long-term pain is examined. Subjects set up for 24-h recordings, but with recording failure early in the leisure period (<4.5 h), they are included in the material limited to work recordings.

On the basis of work title and descriptions of work duties obtained in interviews at the end of the workday, four occupational groups were established: computer operators (help-desk and call center operators; n = 23), secretaries (university secretaries and secretaries in a safety consulting company; n = 34), health care workers (n = 36), and retail workers (n = 25). Computer operators and secretaries had predominant seated work posture, and health care and retail workers had predominant upright standing/ambulating work posture. Computer operators were more intensely locked to their computer workstation than secretaries, who performed general office duties in the private company (18 vs. 24% of working hours in upright posture; unpublished results). The descriptions of work duties for the university secretaries also suggested relatively varied work tasks for this group of workers.

Work recordings were obtained from all of the 118 above-listed subjects, whereas leisure sEMG activity was recorded in 73 subjects (13 computer operators, 32 secretaries, 15 health care workers, and 13 retail workers). The duration of the work recordings ranged from 4.1 to 10.2 h (mean 6.2 ± 0.9 h), and from 4.6 to 10.6 h (mean 8.0 ± 1.3 h) in leisure.

The subjects were, in part, selected from a larger material (37) to include subjects with and without shoulder and neck pain (47). In later studies, inclusion was based on availability but ensuring that subjects both reporting and not reporting shoulder and neck pain were included. Subjects with pain potentially due to injury, diagnosed fibromyalgia, or rheumatological diseases were excluded, as were pregnant women.

Shoulder and neck pain for the last 6 mo was scored on a scale from 0 to 6, by adding intensity and frequency scores (45). The intensity score ranged from 0 to 4, anchored by descriptions of pain hampering daily activities to various degrees, with a score of 0 representing no pain and a score of 4 representing great difficulties of normal functioning due to the pain. The frequency score ranged from score 0 (pain no more frequent than 1–2 times/mo) to score 2 (daily or almost daily pain for a period of >2 wk). Cutoff score for pain-positive subjects was 3, which, in the previous study, represented a 45% chance of seeking a medical consultation due to this pain. This criterion identified 53 subjects with and 65 without shoulder and neck pain. Thirty of the latter group reported no pain, 19 reported infrequent pain (frequency score 0) of slight intensity (only noticeable in pauses; intensity score 1), and 15 reported infrequent pain of an intensity that was just noticeable when performing regular activities (intensity score 2). One subject reported slight pain one to two times per week over a period of at least 2 mo (frequency score 1).

A clinical examination was carried out in the first study (37), including trigger point assessment in the neck and shoulder region (trapezius, infraspinatus, levator scapula, sternocleidomastoid, and suboccipital area) and measurements of range of motion in the cervical column (neck extension, flexion, rotation, lateral flexion). A nonsignificant tendency of increased frequency of pressure-sensitive trigger points in the upper trapezius was found. Beyond that, no differences in range of motion or presence of trigger points were found between pain-affected and pain-free subjects. Therefore, no formal clinical evaluation was carried out in the later studies. Instead, pain location was identified by pain drawings. The extent of the painful region varied but included the location of the sEMG electrodes in the majority of subjects (81%), ranging from an exact pinpoint of this position to including most of the shoulder and neck region. Some subjects drew positions that coincided with the locations of the trapezius myotendinous junction but did not include the electrode position (12%).

The difficulty of reconciling clinical findings with subjectively reported pain is noted in epidemiological studies, concluding that subjectively reported pain is the better indicator of health-related behavior (e.g., Ref. 2). It is emphasized that subjects classified as pain afflicted in the present study do not represent a diagnosed patient population, but they suffer from a subjectively reported ailment. The Regional Ethics Committee approved the study protocol, and all subjects gave their informed consent before inclusion. The study was carried out according to the Declaration of Helsinki.

Physiological recordings. The physiological recordings are described in detail in previous publications (e.g., Ref. 31). Briefly, bilateral sEMG from upper trapezius and electrocardiography (ECG) were recorded over 24 h (Physiometer PHY-400, Premed), except where otherwise stated. Silver-silver chloride bipolar electrodes (Neuroline, Medicotest) with 6-mm diameter were used in the sEMG and ECG recordings. The ECG electrodes were placed in standard positions across the chest. The skin was rubbed with alcohol before application of the electrodes.

For upper trapezius, the electrodes (20-mm center-to-center distance) were placed at a point two-thirds of the distance from the spinous process of the seventh cervical vertebra (C7) toward the lateral edge of the acromion (17). The sEMG signal was band-pass filtered at 20–800 Hz and sampled at 1,600 Hz. The sEMG signals were thereafter analog-to-digital converted, and the root-mean-square value was calculated and transmitted at 10 Hz on a serial interface to a palmtop personal computer carried by the subject (HP 200LX, Hewlett-Packard). The processed signals were analyzed in the labo-
of bursts (bursts/h), and mean burst amplitude (%EMGmax). Figure 1

In the ECG recordings, the QRS complex was detected, and the intervals between the R peaks (R-R intervals) were derived on a beat-by-beat basis. The processed signal was stored synchronously with the sEMG signal. Instantaneous heart rate was determined by inverting the beat-to-beat intervals. A time resolution of 0.2 s was used in the further analyses of ECG and sEMG signals. An indication of resting heart rate was obtained from the 10-min interval with lowest heart rate during leisure. This was found to be similar between groups (mean value 66, 68, and 68 beats/min for low-, intermediate-, and high-response groups, respectively; \( P = 0.68 \)). Subjects were instructed to maintain normal work tasks and leisure activities, except to avoid vigorous physical activity that could potentially dislodge the recording equipment.

Calibration to MVC. The maximal sEMG response (EMGmax) was obtained from a seated posture with both arms 90° abducted in the scapular plane and resistance applied just proximal to the elbow. The subjects performed three or more isometric MVCs until a consistent response was obtained, both at the start and the end of the recording session. The highest sEMG response was used to normalize the sEMG signal. The mean percent difference between EMGmax obtained at the start and the end of the recording session ranged from 5.1 to 6.7% (30, 31). There was no significant difference in EMGmax responses between pain-afflicted and pain-free workers, between occupational groups, or between the response groups analyzed in this study.

sEMG analysis. sEMG activity with amplitude >2% EMGmax was quantified by burst analysis (22). Outcome variables were burst time (percentage of recording period), mean duration of bursts (s), number of bursts (bursts/h), and mean burst amplitude (%EMGmax). Figure 1 shows a 4-min segment of recording illustrating quantification of burst time, rest time, and burst amplitude. The amplitude probability distribution function (20) was used to determine median and static sEMG level, defined as the contraction amplitude below which muscle activity is found for 50 and 10% of the recording period. Rest time was defined as the time with sEMG signal below 0.5% EMGmax. The highest sEMG response was used to normalize the sEMG signal. The mean percent difference between EMGmax obtained at the start and the end of the recording session ranged from 5.1 to 6.7% (30, 31). There was no significant difference in EMGmax responses between pain-afflicted and pain-free workers, between occupational groups, or between the response groups analyzed in this study.

sEMG recordings were sorted into three response categories on the basis of burst time during work (low response: <50%; intermediate response: 50–70%; high response: >70% of recording time). sEMG responses were quantified as the mean of right and left trapezius recordings. If a recording was lost on one side (8 work, 7 leisure recordings), the remaining recording was used to represent that subject.

Subjective variables. Subjects scored their level of shoulder and neck pain, perceived tension, and perceived stress from the environment every hour throughout work and leisure. Considering pain, subjects first checked whether they at all felt pain. In case of a positive response, scoring of intensity was performed on a 10-cm visual analog scale with end points very low and very high. Perceived tension and stress were scored on visual analog scale with the same end points. Average values of the hourly scores were used to compare subjective scores for the work and leisure periods but with scores for the first hour of either period omitted to reduce carryover effects. All subjects responded to a questionnaire (37, 39) that included biographic data (weight, height, number of children), general health (exercise, sleep), psychological profile (perceived tension as an average over last 2–3 mo, general mood, psychological health), physical and psychological exposure factors at work (job satisfaction, social support, job control, self-realization, job instructions, workload, work pace, work place design, load variation, indoor environment), and general psychosocial stress factors (off-work duties, personal economy, family situation).

Statistical analysis. Nonparametric statistical methods were used due to many nonnormal distributions. The Wilcoxon signed-rank test was used to test the hypothesis that subjective scores (pain, tension, stress, heart rate, and sEMG activity within response groups did not differ between work and leisure. The \( \chi^2 \) statistics were used to test the hypotheses that the distribution of pain-afflicted and pain-free subjects, different occupational groups, and seated and standing/ambulating workers did not differ from the expected frequency within the response groups. A nonparametric one-way ANOVA (Kruskal-Wallis) with a post hoc test (Kruskal-Wallis \( z \)-score test) was used to test the hypotheses that subjective scores, heart rate, and leisure sEMG activity did not differ between the three response groups. Spearman’s rho (\( \rho \)) was used for correlation analyses. The Mann-Whitney \( U \)-test was used to test differences between independent groups. A two-way random intraclass correlation analysis was used to assess agreement between work and leisure for mean burst amplitude. All comparisons were performed two-tailed, and a probability level of \( P < 0.05 \) was considered to indicate significant differences.

RESULTS

Table 2 presents sEMG responses and heart rate during work and leisure for subjects with low (<50%), intermediate (50–
Subject distribution for the last 6 mo indicated by solid and open symbols. Note that for the last 6 mo, pain was reported more frequently in the high-response group (54 and 56% for dominant and nondominant trapezius, respectively).

Different symbols. Vertical dotted lines in Fig. 2 indicate bounds of 50% (n = 157) and high (>70%) burst time during the work period. These subjects. If a subject attended both work and leisure, they were included in Table 2. Table 3. Subjects in occupational groups sorted by the three response groups. Burst Time (% of recording time) "deviated from work to leisure for the high-response group (Table 2). Mean burst amplitude deviated by <0.5% EMG_max from work to leisure for more than one-half of the recordings (52 and 54% for dominant and nondominant trapezius, respectively).

Subjects with predominant seated work (computer operators and secretaries vs. health care and retail). Figure 4B shows the relation between burst time and median sEMG level in work recordings, with shoulder and neck pain status for the last 6 mo indicated by solid and open symbols. Subjects with similar, high burst time (80–90%) show variable median activity level mainly due to variation in burst amplitude. Figure 4C shows a scatterplot of mean burst duration vs. number of bursts/h. Burst time is determined as the product of the two variables, and hyperbolas at 50 and 70% delineate borders between response groups. A cluster of subjects with relatively few long-duration bursts (mean burst duration >4.5 s) in the high-response group, all but one with shoulder and neck pain, had significantly higher burst amplitude than the other subjects in the high-response group (6.4 vs. 5.4% EMG_max; P < 0.05). Pain-afflicted subjects in the low-response group were not distinguished from pain-free subjects by any sEMG variable.

There were no statistically significant differences between the occupational groups in the proportional distribution of work and leisure, with considerable overlap between response groups during leisure (Fig. 2C). The distribution of mean burst amplitude in the work period for the three response groups is shown in Fig. 3A, increasing from predominantly 3–5% EMG_max for the low-response group to predominantly 5–9% EMG_max for the high-response group. Burst amplitude was similar in work and leisure (intraclass correlation = 0.77; Fig. 3B), however, with a small reduction from work to leisure for the high-response group (Table 2).

**Table 2. Surface electromyographic responses and heart rate during work and leisure for the three response groups**

<table>
<thead>
<tr>
<th></th>
<th>Burst Time (% of recording time)</th>
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<tbody>
<tr>
<td></td>
<td>&lt;50% (n = 30)</td>
</tr>
<tr>
<td><strong>Work</strong></td>
<td></td>
</tr>
<tr>
<td>Median activity (% EMG_max)</td>
<td>44 (36–46)</td>
</tr>
<tr>
<td>Burst time, %</td>
<td>5.1 (4.6–5.7)</td>
</tr>
<tr>
<td>Rest time, %</td>
<td>1.5 (1.1–1.6)</td>
</tr>
<tr>
<td><strong>Leisure</strong></td>
<td></td>
</tr>
<tr>
<td>Median activity (% EMG_max)</td>
<td>36 (31–41)</td>
</tr>
<tr>
<td>Burst time, %</td>
<td>1.1 (0.9–1.3)</td>
</tr>
<tr>
<td>Rest time, %</td>
<td>3.4 (2.6–3.9)</td>
</tr>
</tbody>
</table>

Values are median with 95% confidence interval in parentheses; n, no. of subjects. Subjects recorded during both work and leisure are included. EMG_max, maximum electromyography; NS, nonsignificant. *Wilcoxon matched-pair test. †P < 0.02, group with burst time <50% different from other groups. ‡P < 0.02, group with burst time >70% different from other groups.

Computer operators (n = 23) 18 (9) 4 (1) 1 (1)
Secretaries (n = 34) 12 (4) 16 (7) 6 (5)
Health care workers (n = 36) 13 (6) 14 (4) 9 (7)
Retail workers (n = 25) 3 (0) 12 (3) 10 (6)

n, No. of subjects. No. of pain-afflicted subjects in each cell of table is shown by no. in parentheses. J Appl Physiol • VOL 100 • APRIL 2006 • www.jap.org
pain-afflicted and pain-free subjects in the different response groups (Table 3). However, the sensitivity of this analysis is low, as the comparison of membership in some cells is based on few subjects. There were no significant associations between perceived tension for the last 2 mo and sEMG activity at work, also when stratified by pain status, response group, and/or occupational group. Response groups did not differ significantly with respect to subjective variables covering biographical data, general health, psychological profile, subjectively reported physical and psychological exposure factors, and psychosocial stress factors.

**DISCUSSION**

The main aim of this study was to establish evidence supporting or negating the hypothesis that shoulder and neck pain is related to sustained activity in low-threshold trapezius motor units. Two comparisons were performed: trapezius activity and pain score in work vs. leisure and, in a larger material, trapezius activity at work vs. long-term shoulder and

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**Fig. 2.** Scatterplots showing associations of sEMG variables [burst time (A), median EMG level (B), rest time (C)] between the work and leisure periods. Subjects are categorized into 3 response groups (low, intermediate, high) by their burst time (<50, 50–70, >70% of recording time, respectively), which are identified by different symbols. Borders between groups are indicated by vertical dotted lines in A. Mean of dominant and nondominant recordings are shown. Line of identity is shown.

**Fig. 3.** A: histogram of mean burst amplitude (%EMG\textsubscript{max}) in the work period for low-, intermediate-, and high-response groups (n = 118). B: scatterplot to show association of mean burst amplitude in work and leisure for subjects with recordings in both periods (n = 73). Dominant and nondominant recordings are shown separately. Line of identity is shown. Trap, Trapezius.
neck pain. The work period was indicated as critical for pain development by hourly pain scores showing higher and augmenting pain during work vs. lower and receding pain during leisure (this study and Ref. 11). Trapezius activity was characterized by duration and amplitude of sEMG bursts, which are more readily interpreted in terms of duration of low-threshold motor unit activity than more commonly used variables such as median activity level. Burst time rather than occupational group membership was used in the stratification of the material, the analysis thereby deviating from studies that aim to detect and quantify environmental exposure hazards (including previous analyses of part of this material). It is considered that the sEMG activity is representative for the subject, i.e., represents the habitual trapezius activity pattern free of unusual force requirements in work and leisure (31).

Trapezius activity pattern seems unable to account for shoulder and neck pain for pain-afflicted subjects in the low-response group. The duration of rest time, which, for trapezius, represents periods of activity with no more than two to three motor units firing (42), was about one-third of the recording time during both work and leisure. Thus also the lowest threshold motor units benefited from long periods of rest. Burst time, burst amplitude, and rest time did not change from work to leisure, when pain scores were lower. Higher threshold motor units were active for very short periods of time (31).

Trapezius activity is thereby indicated not to be a prerequisite for pain comprising this muscle. Most computer operators with call-center or help-desk work duties, an occupational group considered at risk of developing shoulder and neck pain (4, 16, 32), belong to the low-response group.

The reasoning in the previous paragraph rests on the assumptions that sEMG cross-talk effects can be ignored and that

| Table 4. Mean hourly scores of pain in neck and shoulders, perceived tension, and stress during work and leisure |
|---|---|---|---|
| Burst Time (% of recording time) | <50% (n = 30) | 50–70% (n = 27) | >70% (n = 16) |
| Pain Work | 1.6 (0.9–2.3) | 1.3 (0.6–2.0) | 3.3 (2.1–4.4)† |
| Leisure | 1.3 (0.6–2.0) | 0.9 (0.3–1.4) | 2.6 (1.8–3.5)† |
| P* | 0.07 | NS | NS |
| Tension Work | 2.9 (2.2–3.5) | 2.8 (2.1–3.4) | 3.6 (2.6–4.5) |
| Leisure | 1.8 (1.1–2.6) | 1.5 (1.0–2.0) | 2.5 (1.6–3.4) |
| P* | 0.003 | 0.001 | 0.02 |
| Stress Work | 3.2 (2.5–3.9) | 3.0 (2.3–3.7) | 3.6 (2.7–4.5) |
| Leisure | 1.6 (1.0–2.3) | 1.6 (1.0–2.1) | 1.9 (1.1–2.6) |
| P* | 0.001 | 0.001 | 0.002 |

Values are means with 95% confidence interval in parentheses; n, no. of subjects. Subjects recorded during both work and leisure are included. *Wilcoxon matched-pair test. †P < 0.007, group with burst time >70% different from both of the other groups.

Fig. 4. A: distribution of pain-free and pain-afflicted subjects (with respect to reported pain for the last 6 mo) within burst time response categories. Percent distribution within each of the response groups is shown, with no. of subjects indicated above each bar (n = 118). B: scatterplot of median EMG level (%EMGmax) vs. burst time (% of recording time). Vertical arrows indicate borders between response groups. C: scatterplot of mean burst duration (s) vs. no. of bursts/h. Hyperbolas indicate burst time (% of recording period), which is the scaled product of the 2 variables. Hyperbolas at 50 and 70% delineate borders between subjects in the low-, intermediate-, and high-response groups. Note that data points, based on mean values of dominant and nondominant side, may misrepresent burst duration when there are significant side differences in activity pattern, due to the nonlinear relationship between variables. For most recordings, the discrepancy can be ignored; however, the data point marked by an arrow overrepresents burst time (mean burst duration was 2.2 and 6.6 s for left and right trapezius, respectively; the correct value for mean burst time is 76% rather than the indicated 95%).
upper trapezius (more specific, the segment contributing to the sEMG signal) is a primary location of shoulder and neck pain for the subjects in the study. Cross talk between neck muscles (i.e., trapezius, scalenii, sternocleidomastoides, posterior neck muscles) were examined in a recent study (33), and no evidence of cross talk was found. The underlying supraspinatus muscle is active in arm abduction (14, 25) and may contribute to sEMG recorded activity during arm movement. Such contribution is likely to be moderate, with the supraspinatus surface 13–15 mm below the sEMG electrode for the preferred electrode location (15). Higher sEMG response in MVC with arm abduction, relative to arm elevation, is reported (27), which may show a contribution from supraspinatus, but this pattern was not observed at the relevant electrode position in another study with conventional and double differential (i.e., more localized) recording (19). Furthermore, a contribution to the sEMG signal from supraspinatus does not influence a conclusion based on observation of trapezius inactivity. Another critical aspect is whether pain is related to muscle activity not observed by the recording electrode. This seems unlikely, as the recording position corresponds well to the location of nonspecific shoulder and neck pain in clinical examination (35), and the recordings are representative of a wider area of upper trapezius, although with some task-dependent variation in the distribution of trapezius sEMG activity (18).

The results for the high-response group are consistent with the hypothesis of sustained activity in low-threshold motor units related to shoulder and neck pain: burst time was substantially reduced from work to leisure, indicated as a low-risk period. Previous studies of subjects with still higher sEMG activity levels and high prevalence of shoulder and neck pain provide supporting evidence for muscle fiber overexertion at high sEMG activity levels (e.g., Refs. 8, 46). The results are, however, no proof of pain causation from metabolic injury to muscle fibers, if pain also can develop independently of muscle activity pattern.

The marked reduction in heart rate from work to leisure is notable, considering the low level of physical activity at work. Circadian variation seems unable to fully explain this reduction (e.g., Refs. 1, 5). Elevated heart rate during work for the low-response group may be a response to work stress, as indicated by the subjective scores of stress and perceived tension (10, 12, 39, 41).

Subjects with shoulder and neck pain have significantly more trapezius activity during sleep (median activity 0.5 vs. 0.2% EMGmax; Ref. 30), when the activity pattern is clearly influenced by the autonomic nervous system (44). The numeric values of these responses are small and would seem of little consequence for the development of shoulder and neck pain. A possible explanation is that trapezius activity during sleep, or as a stress response, is a pointer to parallel physiological responses more critical to pain development. It is commonly assumed that shoulder and neck pain due to stress has its effect by promoting motor unit activity and thereby is quantified as a biomechanical load by sEMG recordings (29, 36). The results of this study suggest that this is an overly simplified model.

Finally, consistent burst amplitude between work and leisure supports the hypothesis of idiosyncratic activity patterns for postural muscles. The small (0.7% EMGmax) reduction in trapezius burst amplitude from work to leisure for subjects in the high-response group may be explained as a change from mainly upright to habitual seated posture, as we have observed this effect in intrasubject comparisons when changing between upright and seated postures (unpublished observations).

In conclusion, two separate mechanisms of shoulder and neck pain involving the trapezius muscle are indicated. One mechanism may relate to prolonged activation of low-threshold trapezius motor units, whereas the other mechanism appears to operate independently of sustained activity in low-threshold trapezius motor units.

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