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Exploring perceived tension as a response to psychosocial work stress

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Exploring perceived tension as a response to psychosocial work stress

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Objectives This study extends the concept of tension, in part by observing changes in tension during the workday, to identify episodes causing elevated tension and relate them to bodily responses.

Methods Both questionnaires and qualitative interviews were used to describe the tension concept. Tension was scored on a visual analogue scale (VAS) every hour, and trapezius muscle activity and heart rate were recorded. Ninety-four female workers from four service occupations participated.

Results Tension was described as a musculoskeletal activation response involving the upper body regions, but also autonomic activation responses were described. The cause of elevated tension comprised a variety of situational demands; however, contact with other people causing negative emotions was a common factor. Averaged muscular activity and heart rate responses did not correlate with prolonged perceived tension, but the differential tension score between high- and low-tension periods correlated with the corresponding differential trapezius activity responses. The regression line indicated no effect of short-term variation in perceived tension on median muscle activity for differential VAS scores of ≤2 cm. An increase of 2% of maximal electromyographic activity for a differential VAS score of 4–5 cm was indicated.

Conclusions This study identifies work exposures that cause tension, and it demonstrates a physiological correlate with the subjective perception of tension in the short term. The low recorded muscle activation response does not represent a risk factor for pain by the traditional standards used for recording and evaluating muscle activity responses, but it may point to underlying pain-inducing mechanisms, such as low-threshold overexertion of motor units.

Key terms electromyography, psychosocial factors, service occupations, stress, trapezius.

The variable "perceived general tension", describing a prolonged sensation of tension, has shown a strong and consistent association with pain in the shoulder and neck in several studies from this laboratory (1–3). Often this was the only variable to be associated with shoulder and neck pain. Similar results have been reported by others; the variable "muscle tension", integrating questions on raising shoulders and contracting neck muscles, was significantly associated with pain in the neck and shoulders and with emotional and mental stressors (4). Likewise, the variable "tense" has been shown to be associated with shoulder and neck pain (5). In one study the subjective tension level correlated significantly with some of the variables quantifying trapezius activity during work (6); however, this association was not observed in other studies (7, 8).

The cited results show that a sensation of tension is often associated with shoulder and neck pain, although the temporal and causal relationships between the two variables are unclear. In an earlier report dealing with the same cohort of service workers that was used in this study, perceived general tension was again higher for workers with shoulder and neck pain than for pain-free workers (9). Short-term perceived tension (ie, the mean of hourly scored tension over the workday) also distinguished between workers with and without shoulder and

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neck pain (10). Both pain-afflicted and pain-free workers reported an increase in tension during workhours that receded during leisure time. These results showed that the tension concept is meaningful over shorter time periods. However, a sensation of tension that fluctuates over short periods is probably normal and does not necessarily represent a risk for the development of pain in the shoulder and neck.

In an earlier publication, we hypothesized that perceived general tension is an intermediate response variable between environmental stress and shoulder and neck pain (7). Tension can be described both as an immediate or rapidly changing perception and as a long-duration state; however, we know in little systematic detail what this commonly used term entails. Therefore in our present study, we hypothesized that perceived general tension, extending over long periods, and the short-duration tension response represent a similar response mechanism and respond to the same stressors. A corollary is that perceived general tension, which we have used to express an averaged, long-term sensation of tension, can be meaningfully explored by studying the dynamic tension response pattern over a day. Information about personal factors and work exposures that may be associated with perceived general tension was collected by questionnaires. Verbal descriptions of sensations and environmental factors (exposures) perceived to be associated with tension were obtained. Trapezius muscle activity and heart rate were recorded over a workday. The aim of this study was to investigate workers' perception of tension in terms of other sensations and identify work exposures that cause long- or short-term elevation of tension. We further examined whether short-term tension responses are associated with trapezius muscle activity or heart rate.

Subjects and methods

Study design

The study combined a case study design using qualitative methods with a cross-sectional study design using quantitative questionnaires. Data were further collected through a semi-experimental design with physiological recordings and repeated measurements of perceived exposures over the workday. Figure 1 presents an overview of the study design and the material collected for this report. Other results from this study, in part based on material not shown in figure 1, have been presented in other reports (9–11). The case study design was useful, as we aimed to explore how the informants perceived tension and why they perceived elevated tension. According to Yin (12), a case study is the preferred strategy when "how" or "why" questions are posed when the investigator has little control over events and when the focus is on a contemporary phenomenon within a real-life context.

Tension concept and nomenclature

In this study the tension concept was explored in different ways that put different factual meaning to the term. Tension is a commonly used expression in everyday language, and the term "tension" is used when referring to the perception of bodily tension in general. This was also the starting point of the qualitative interviews (ie, the respondents were asked to clarify their conceptualization of the term without keywords or other delineators). The respondents were also asked to score their level of tension on a visual analogue scale (VAS), both as an average over the last two months ("perceived general

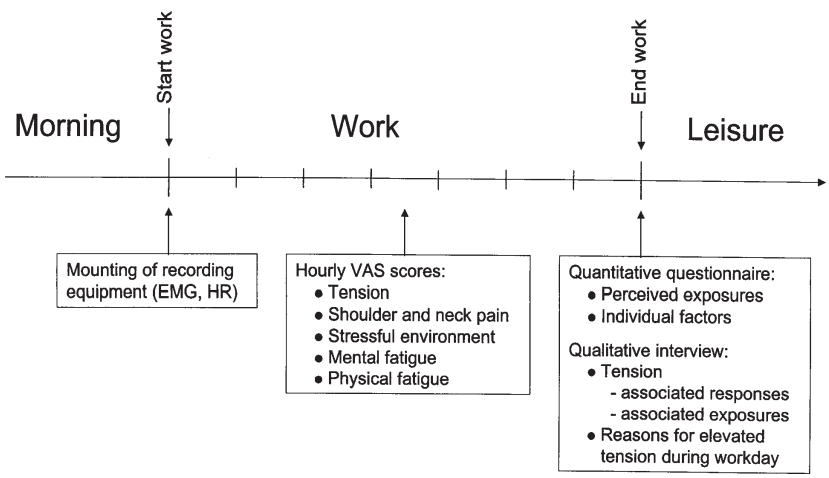

Figure 1. Graphic representation of the study design shown by a time line. Physiological recordings and hourly VAS scoring continued in the leisure period, but was not part of the material for this study. (EMG = electromyography, HR = heart rate, VAS = visual analogue scale)

tension") and as an average of the last hour ("hourly tension"). Perceived daily tension (daily tension) was calculated as the mean of the hourly responses during work. Perceived general tension and hourly tension during work were scored before the qualitative interview, on the basis of the respondents' intuitive understanding of the tension term.

Subjects

The study group comprised 94 women in health care (N=20), banking (N=26), retail (N=22), and secretarial work (N=26). Their mean age was 43 (SD 9) years, and the mean of their employment time was 9 (SD 8) years. The health care workers were recruited from two health service centers for elderly people with nursing homes, day-care centers (also for dementia sufferers), and units for home-based service. Nurses, auxiliary nurses, home care, and administrative personnel were represented in the material. The bank workers were cashiers and customer consultants. The cashiers performed routine tasks such as payment of bills, money transferal, establishment of new accounts, and the like. Customer consultants handled loan applications and economic planning. The retail workers carried out sales work in two small shopping centers. Their main work duty was to serve customers and induce sales. The university secretaries were employed in university administration. They assisted students and the administrative and scientific staff of the university. A detailed description of work duties has been given elsewhere (10).

Questionnaires

A package of self-constructed questionnaires, including questions on biographical data (weight, stature, number of children), general health (exercise, sleep), psychological profile (perceived general tension, general mood, mental health), subjectively reported physical and psychosocial exposure factors at work (load variation, workplace design, indoor environment, workload or workpace, job control, job satisfaction, social support, self-realization, job instruction) and general psychosocial stress factors (off-work duties, personal economy, family relations) was presented to the subjects. The questions on physical and psychosocial exposure were phrased in terms of satisfaction with the given exposure factor, and the responses were scored on 10-cm visual analogue scales (VAS) with the end phrases "very dissatisfied" and "very satisfied". The variable mental health was a self-evaluation on a VAS from "very poor" to "very good". A detailed description of the questionnaires has been given elsewhere (2). The questionnaires also included the neuroticism index (EPQ-N) of the Eysenck Personality Questionnaire (13). The reliability of the self-constructed questionnaires has been tested and found acceptable (3).

On the day of the recordings the subjects scored perceived tension (hourly tension), pain in the shoulder and neck, perception of a stressful work environment, and mental and physical fatigue every hour as a mean of the preceding hour (VAS, end points "very low" and "very high"). Physical fatigue was scored on a 10-division Borg scale (14).

Interview

Sixty-four informants were interviewed regarding the tension concept and causes of tension, all the interviews were carried out by the same researcher. The qualitative interview was not carried out for 11 of the bank workers in the beginning of the study. Nineteen secretaries were interviewed by phone towards the end of the series, and questions on tension were left out. The interview was carried out at the end of the workday, supported by use of an interview guide. In the part of the interview covering the tension concept, the informants were first asked about their interpretation of perceived tension, presumably reflecting perceived general tension. In a few cases in which the subjects had difficulties in describing this experience, key words related to muscles, body location, pain, and responses in the body were given. During the interview the scores of hourly tension and perceived stressful work environment were examined. If a marked difference between the highest and lowest scores was found, the subject was asked why periods of elevated tension and work stress had occurred, posed as two separate questions.

All the interviews were tape-recorded and later transcribed to text files. The text analysis was carried out by open coding whereby key words or phrases were noted and labeled (15). The labels were grouped into categories that developed naturally. Each interview was thereafter repeatedly checked to ensure that the classification of the responses was consistent.

Physiological recordings

Muscle activity in the upper trapezius was quantified by a bilateral recording of surface electromyography (EMG) (Physiometer PHY-400, Premed A/S, Oslo, Norway). Bipolar electrodes, 6 mm in diameter (Blue Sensor, E-10-vs or Neuroline 725-01-K, Medicotest A/S, Ballerup, Denmark), with a center-to-center distance of 20 mm, were placed at a point two-thirds of the distance from the spinous process of the seventh vertebra (C7) to the lateral edge of the acromion (16). The signal was sampled at 1600 Hz and band-passed filtered at 20–800 Hz. An artifact detection procedure sensitive to sharp transients and slow deviations from the

signal baseline (400-ms period) was performed on the raw electromyogram (EMG). The signal was analogue/digital converted, and the root-mean-square (RMS) value was calculated and transmitted at 10 Hz (100-ms time window) on a serial interface to a palmtop personal computer carried by the subject (HP 200LX, Hewlett-Packard, Palo Alto, CA, USA). The processed EMG signals were later analyzed in the laboratory on a personal computer by use of Physiometer software (Premed A/S, Oslo, Norway). A time resolution of 0.2 seconds was used in the analysis. The signal was calibrated by the highest EMG amplitude of three maximal arm abductions at 90 degrees (%EMG_{max}), performed both before and after the recordings (17).

The static and median muscle activity levels, defined as the 10 and 50 percentile of the cumulative distribution curve of the EMG activity over the period considered, were determined (18). The EMG rest time was quantified as the total time with the EMG level lower than 0.5% EMG_{max}, previously termed "gap time" (19). The side with the highest EMG response of the right and left trapezius (for static and median activity level) and the least rest time (for EMG rest time) was considered most at risk of musculoskeletal complaints and used in the analyses (ie, different sides of the same subject could be represented in the analysis, depending on the EMG variable considered). Heart rate (beat-to-beat interval) was recorded simultaneously with the EMG signals and stored on the same recording unit.

Analysis of hourly scores and associated physiological recordings

The physiological recordings were partitioned into 1-hour periods that preceded the times of the VAS scoring. The time series of the hourly tension scores were visually inspected, and those showing a variation of 25 mm or higher during the work period were selected. The periods of high and low hourly tension often extended over several hours and the mean score of the extended periods was calculated (mean duration of 1.9 hours for the high score periods and 1.6 hours for the low score periods). The variation in the tension score was <15 mm for the high-score periods and <11 mm for the low-score periods, and a clear delineation of the high and low tension periods was observed. The researcher deciding on the duration of the high- and low-tension periods was blind to the results of the physiological recordings. Mean tension in the high- or low-tension periods and the corresponding mean values of muscle activity and heart rate were determined. Covariation was examined in correlation analyses. High and low periods of the variable "stressful work environment" were determined by the same procedure (ie, the duration of periods with high and low stress scores was decided by visual inspection of the time series and the associated physiological variables were calculated). Finally, differential heart rate was compared with the differential VAS scores.

Statistics

When evaluating the univariate association between perceived general tension or hourly tension and the continuously distributed variables from the questionnaire and the hourly VAS scores, respectively, the Pearson correlation coefficient was calculated. The significant questionnaire variables in the univariate correlations with perceived general tension were fed into a stepwise multiple linear regression analysis to examine their multivariate association with perceived general tension (dependent variable). The Spearman rank correlation coefficient (ρ) was calculated in the comparison between tension and the EMG variables, in compliance with the data distribution. The association between the differential hourly tension and work stress VAS scores on the one hand and the differential EMG responses on the other was primarily tested by Spearman rank correlation; the Pearson correlation analysis was used to establish regression lines. A P-value of <0.05 (two-tailed) was considered to indicate statistical significance.

Results

Questionnaires and interview

Most of the subjects had an intuitive understanding of the "tension" concept (corresponding to "perceived general tension") and described tension as a bodily response (table 1). Fifty-two subjects (81%) offered descriptions considered to represent an activation of the musculoskeletal system. A typical description of tension as a musculoskeletal activation response was given by a retail worker (45 years): "… tense? I can be tense the whole day and then I have elevated shoulders. If something special happens I elevate [the shoulders] even more. Don't know why I do this and it is often subconscious. Cannot relax. I notice I elevate my shoulders when I watch television and then I think now I must lower my shoulders." A common statement in this group was the inability to relax. Forty-two subjects (65%) located their musculoskeletal response to the upper body, often specified as elevation of the shoulders. The rest related their description to whole-body responses. Muscle pain or headache was described as a consequence of feeling tense over a long time. Headache could develop when they tried to relax. Autonomic activation responses (ie, abdominal, respiratory, perspiration, or circulatory

Table 1. Bodily responses that the subjects associated with the term "tension", as categorized by the physiological system activated (64 subjects presented 89 entries).

Category	Distribution		Common statements
	N	%	
Musculoskeletal activation	52	81	Not being able to relax; tensing up (ie, as in muscle activation); tense muscles
Autonomic activation			
Abdominal	11	17	Stomach pain; dyspepsia
Respiration or perspiration	12	19	Do not breathe properly; forget to breathe; clammy hands; sweating
Circulatory	4	6	Pounding heart; red flushes
Other	10	16	Exhaustion; pain; restlessness; mental reaction; unknown

Table 2. Univariate correlations between "perceived general tension" and the questionnaire variables, as grouped in the general health and workplace factors. Pearson correlation coefficients and P-value are shown (N=94). (NS = not significant)

Variable	Pearson correlation coefficient	P-value
Personal or general health factors		
Mental health	0.44	0.00002
EPQ-N [a]	0.33	0.002
Sleep quality [b]	0.34	0.003
General mood	0.30	0.01
Family relations	0.27	0.02
Exercise [b]	–0.27	0.02
Off-work duties	0.12	NS
Personal economy	0.07	NS
Workplace factors		
Job satisfaction	–0,33	0.004
Workplace design	–0.31	0.009
Load variation	–0.29	0.01
Self-realization	–0.28	0.02
Job instructions	–0.23	0.05
Social support	–0.20	NS
Job control	–0.17	NS
Workload or pace	–0.12	NS
Indoor environment	–0.12	NS

[a] Neuroticism index of the Eysenck Personality Questionnaire (11).
[b] Categorical scale.

responses) were described by 27 subjects (42%), including some who also identified a musculoskeletal response. Finally, 10 subjects (16%) were difficult to categorize, including three who were not familiar with the tension term.

Many of the subjects spontaneously offered examples of everyday situations inducing elevated tension. Ten described worry about an anticipated situation ahead of time. Thirty-three described short- and long-lasting situations that caused tension at the time, in most cases episodes of psychosocial stress. Both work and off-work experiences were described, including time pressure (19 subjects), exchanges with other people (9 subjects), and various challenging deviations from work routines (5 subjects). Such deviations could be task-oriented or emotional, involving other people. Four subjects described tension as a mobilization or fatigue response when they performed physical worktasks. Another four described tension as something they experienced after active periods, when they should be unwinding.

Table 2 presents the univariate correlations between perceived general tension and the variables from the questionnaire. The variables are grouped into the following two main categories: personal factors plus general health and workplace factors. Mental health and job satisfaction (ie, the most significant variable in each group) were the only variables retained in the multivariate regression equation (r=0.59). This result indicates that both work environment and personal factors contributed to the perception of tension.

Perceived tension on the day of the physiological recordings

Forty-five informants scored a difference of more than 25 mm between the high and low tension periods and were asked about their reasons for the elevated hourly tension. Table 3 presents a summary of the responses by category. Emotional dimensions are listed and exemplified by citations. Eighteen subjects identified client or customer behavior as a cause of elevated tension. Duties independent of clients and customers, but often involving colleagues, were the cause of elevated tension for nine subjects. Twelve subjects identified time pressure or workload, pointing to work-intense periods with customers or clients. In descriptions of specific events, words indicating negative emotional involvement were used, like "irritated", "angry", "nervous", or "resigned". In addition to the 12 subjects only stating time pressure, another 13 identified time pressure as an aspect of the stressful experience even though other demands were considered the main stress, as listed in table 3. Only three subjects identified biomechanical exposure as a cause of elevated tension.

Table 3. Self-reported reasons for elevated "hourly tension" during work for the subjects with a difference of 25 units between the highest and lowest hourly score on a visual analogue scale. Forty-five subjects presented 48 entries, including 4 subjects who were unable to identify a specific reason.

Category	N	%	Emotional dimension [a]	Comment (examples of citations)
Time pressure	12	27	Not specified	Too much to do; we had to hurry; the worktasks accumulated during the workday
Interpersonal relations	22	49	Response to unanticipated behavior (9)	I visited a client that fainted, I had to call the physician; the client did not want to cooperate; customers arrived unexpectedly; customers expected feedback on short notice
			Threatening behavior of customers (2)	Many of the drug addicts and alcoholics came in from outside the store this morning . . . . Got nervous . . . . Some can be threatening – I got hit in my stomach once; the customers who pass the line and go directly to the cashier – they come close to you in a way you don't like
			Irritation and frustration with customers (7)	I had to spend much time discussing – I became exhausted and resigned; customers fussing; many kids – they quarreled and threw goods all around – I got angry; got irritated with a customer who showed up right before closing time; during a day I call people that do not pay on their loan – I had three calls like that today
			Irritation and frustration with colleagues (4)	Got irritated with my colleague – she had so many phone calls; I worked on a case where I had to make some effort thinking through and discussing with my colleagues; I had to follow up something that other colleagues did not do
Deviation from regular work	5	11	Worry or concern	I was in a different group today … do not know the routines … and you do not know how the other person works with you and if you can finish the job; today the computer system has been down – more stressed because you do not know what to do and must ask others for help
Biomechanical	3	7		When we get the clients to bed – that is when we do the body work
Other	2	4		Get more exhausted in the evening; headache
No specific reason	4	9		

[a] Number of respondents in parentheses.

Perceived work stress was separately probed at the end of the work period regarding reasons for an elevated VAS score. The questions on perceived work stress and tension were distinguished by pointing to a work exposure ("stressful environment") and a bodily response ("tension"), respectively. There was considerable overlap in the responses to the two questions; however, the perceived causes of elevated tension and work stress were distinctive for 15 subjects. Of these, 11 subjects associated elevated tension with a negative emotional situation involving other persons. Twelve subjects associated elevated work stress with time pressure or high workload without mentioning any emotional qualities.

Mental fatigue was the only hourly scored variable that co-varied with hourly tension (r=0.40, P=0.02) when the designated high- and low-tension periods were compared. The recordings of shoulder and neck pain, work stress, and physical fatigue did not correlate with hourly tension. Daily tension and perceived general tension were compared, and they showed a clear correlation, but with considerable scatter from the regression line (figure 2). The subjects with low perceived general tension had, on the average, higher scores for daily tension, while the reverse association was true for those with high perceived general tension.

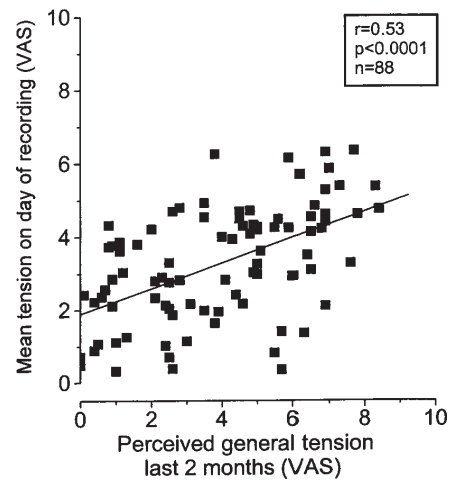

Figure 2. Scatter plot of perceived general tension the last two months (PGT) versus mean tension on the recorded workday (daily tension). Scoring on a visual analogue scale (VAS) was used for both variables; daily tension is the mean of the hourly tension score during work. The Spearman and Pearson correlation coefficients were equal.

Physiological recordings

Large interindividual variation was observed in the EMG responses; this occurrence improved the sensitivity in detecting associations between the EMG variables

and tension. Nevertheless, perceived general tension, hourly tension, and daily tension did not correlate with static or median EMG activity or with EMG rest time in the corresponding time periods. In contrast, the increase in hourly tension from the low to high periods was associated with increased median EMG activity (figure 3A) and reduced EMG rest time (figure 3C). The regression line indicates that an increase of 4 to 5 cm in hourly tension is associated with an increase in EMG activity of about 2% EMG_{max}. If one outlying data point in the two scatter plots is removed (arrows in figure 3A & C), the correlation was strengthened for the median EMG activity (ρ=0.45, P=0.001), but was reduced and no longer significant for rest time (ρ= –0.20, P=0.09). The same procedure of comparing changes in a perceived stressful work environment with the corresponding changes in the EMG variables showed no significant associations (figure 3B & D). Heart rate was elevated in the high-tension versus low-tension periods (88 versus 85 beats/minute, P<0.01), but did not show a differential association with hourly tension.

Some workers described worktasks with a biomechanical exposure component (eg, putting patients to bed) in their high-tension period; others described situations with predominant mental or emotional stress (eg, participating in meetings or dealing with difficult customers). If only those with elevated tension due to mental or emotional stress were included, the correlations between tension and muscular activity strengthened (median EMG activity: ρ=0.59, P<0.001; EMG rest

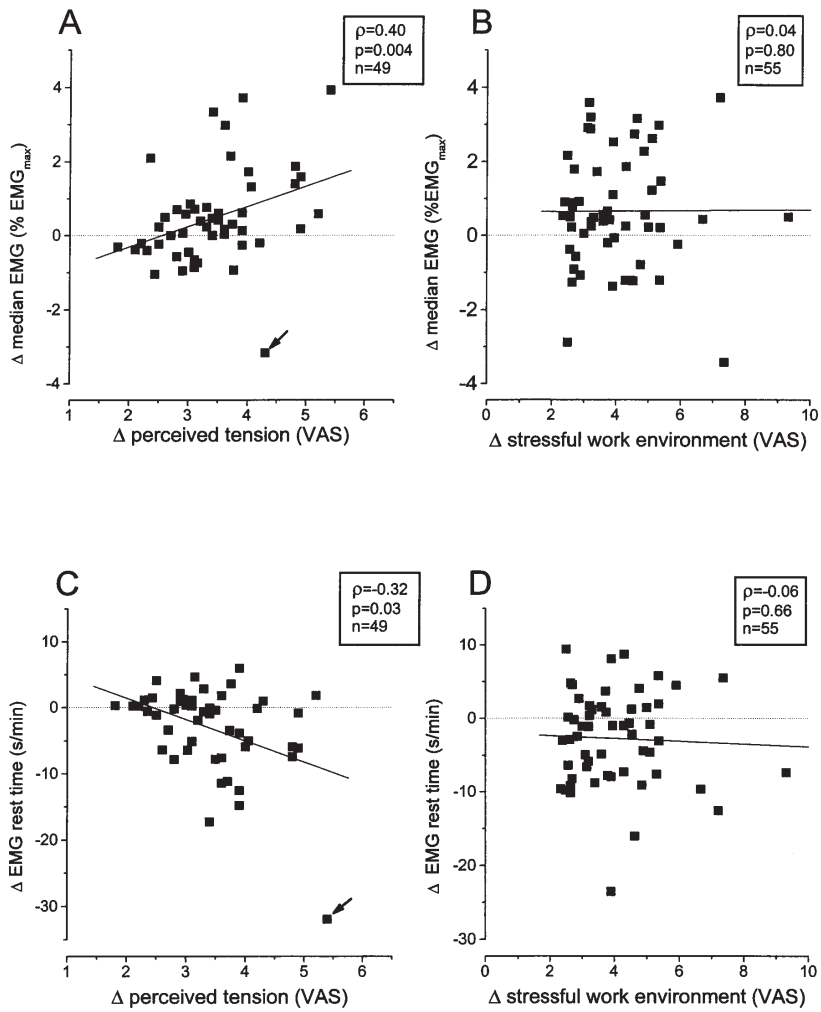

Figure 3. Difference between the periods of high and low perceived tension during the workday versus the corresponding difference in median trapezius electromyographic (EMG) level (A) and EMG rest time (C). Arrows mark data points considered outliers. Similar scatter plots of the differential score between the highest and lowest periods of a stressful work environment versus the corresponding difference in median EMG level (B) and EMG rest time (D). Spearman rank correlation coefficients (ρ) are shown in boxes. The regression lines are based on a Pearson correlation analysis. The Pearson correlation coefficients were 0.34 (P<0.02, median EMG activity) and –0.40 (P<0.005, EMG rest time) for the tension plots (A, C) and 0.06 (P=0.69, median EMG activity) and –0.19 (P=0.18, EMG rest time) for the "stressful environment" plots (B, D).

time: ρ=–0.48, P=0.007; N=29). There was no improvement in the correlation between a stressful work environment and muscular activity if the workers indicating a biomechanical exposure component in their high-stress period were excluded (work stress versus median EMG activity: ρ=–0.02, P=0.92; work stress versus EMG rest time: ρ=0.02, P=0.91; N=30).

Discussion

Tension as a critical response variable to psychosocial stress

The association between perceived general tension and the questionnaire variables indicates that both the work environment and personal characteristics contribute to workers' state of tension. The specific descriptions of exposure situations that cause high tension reflect the study setting, comprising an all-female study population of service workers; however, the impression of tension as an emotional stress response caused by close contact with other people in combination with a demand for good performance was noted. The significant relationship between muscle tension and emotional states like worry and anger in a Swedish study, based on six different occupations, indicates that negative emotions are generally causative in tension development (4). Tension appears to be distinguished from a "stressful environment" as a putative risk factor for shoulder and neck pain. Tension, more than a stressful environment, was associated with negative emotional responses in the interviews. A differential association of the two variables with shoulder and neck pain was observed: pain-free and pain-afflicted workers perceived their work environment as equally stressful, but the pain-afflicted workers reported higher tension during work (10).

The descriptions of reasons for elevated tension in the qualitative interview were supported and elaborated in the description of events causing tension the same day. The variety in such situations is striking. From a work environment perspective, it appears that simply scoring stress level or using simple checklists to evaluate the psychosocial work environment is likely to be inadequate as a basis for psychosocial intervention. Furthermore, tension arises in the interaction between a person and his or her surroundings. An intervention effort that aims to lower tension, and thereby potentially reduce the occurrence of shoulder and neck pain, must consider this interaction for the best result. Primary interventions to reduce work-related musculoskeletal disorders traditionally aim to improve the work environment independently of the worker (20). The problem for these workers is related to the nature of their work, which is not easily changed, and alternative intervention approaches focusing on the individual worker should be considered. Coping with stress seems to be important in this respect; the processing of external stimuli and the expectancy of the outcome determine whether a stimulus is "stressful" or not (21). Coping is defined as expectancy of a positive response outcome, and it is important for subjective health complaints, in particular muscular pain (22).

Tension as a musculoskeletal activation response

We have previously found an inconsistent association between perceived general tension and muscular activity. Some evidence was found for a correlation between perceived general tension and muscular activity in a group of workers performing predominantly manual work, but this was not the case for another group of office workers (7). Our present study shows the same lack of association between average muscular activity at work and perceived general tension, hourly tension, or daily tension (see also reference 8), but it extends the previous results by showing an association of trapezius activity with hourly tension in intrasubject comparisons of high- and low-tension periods on the same day. The low activation response of the muscle (≤2% EMG_{max}), relative to the individual variation in upper trapezius usage (typically 2–10% EMG_{max} in these work situations) helps to explain why no association was found between tension and trapezius activity in straight comparisons. The EMG response is consistent with the perception of tension as an elevation of the shoulders, and the statistical significance of this association is strong, especially when subjects experiencing evident biomechanical exposure in the high-strain period were excluded. However, variation in EMG activity within the high- and low-tension periods was observed, and the differential tension and EMG responses were no longer significantly correlated if the high- and low-tension periods were restricted to the 1 hour of the extreme score. The association between perceived general tension and the EMG variables is therefore at best an indication of a low-level physiological response that should be confirmed by other studies. The contrasting behavior of "perceived tension" (highly significant association) and "stressful environment" (no association) with respect to EMG activity is nevertheless interesting. A possible interpretation is that the "objective" description of the environment is a less precise pointer to a physiologically relevant response and, potentially, harmful health effects in the longer term.

The indication of stress-induced muscular activity in ambulatory recordings is consistent with laboratory studies, which first demonstrated muscular activation responses to cognitive and emotional stress early in the last century (23–25). Such responses were later

demonstrated in simulated work situations (26–28). The contrasting findings of a low muscular activation response and a high consistency of perceived general tension in association with shoulder and neck pain can be resolved in at least two ways, disregarding central mechanisms in pain induction and the possible contribution of other shoulder and neck muscles to pain. The physiological risk factor may be sustained activation of low-threshold motor units not quantified by surface EMG, compare the "Cinderella" hypothesis (29), or a parallel activation of other physiological systems that is more critical to pain development (30). Tentative evidence exists in support of either alternative. Sustained activation of low-threshold motor units during stress has been demonstrated (31) and stress-induced shoulder pain has been associated with low-level trapezius activity in the laboratory (32). Conversely, stress activates many physiological systems (33, 34), and the subjects in our present study described autonomic activation responses during high-tension periods. Localized physiological responses in patient groups with shoulder pain, possibly involving sympathetic activation of muscle spindles, have been reported (35). Currently, no definite conclusion can be drawn regarding the physiological mechanisms that induce or exacerbate stress-induced shoulder and neck pain.

Tension as state or trait

Perceived general tension is elucidated in this report through an examination of the causes of hour-to-hour changes in a similar descriptive variable, hourly tension. Tension, as a short-lasting stressor response, is not a threat to health; such responses are a healthy and necessary aspect of life (36). Hour-to-hour observations of changes in tension may, however, still be a valid pointer to harmful psychosocial exposures in the longer term, by analogy with the concepts of allostasis and allostatic load. Allostasis is defined as the ability of the body to increase or decrease vital functions to meet a new steady state of challenge, while long-term effects of physiological responses to stress are referred to as allostatic load (37, 38). The pathway from allostasis to allostatic load is associated with frequent stress, no adaptation to repeated stressors, inability to shut off allostatic responses after stress is terminated, and compensatory increases in one physiological system due to inadequate responses in other systems (38, 39). The transfer from a short-lasting tension response to a chronic tension state may follow one of several physiological response pathways; however, an activation mechanism involving shoulder girdle muscles seems prominent.

A future research question is whether and how work organizational and psychosocial factors are causal with respect to musculoskeletal disorders. It is suggested that new research paradigms are needed to study dynamic processes associated with these factors (40, 41). The monitoring of tension can be a useful intermediate response variable in this respect. Likewise, it appears that a study design that includes qualitative methods can be a useful supplement to traditional epidemiologic methods.

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References

1. Westgaard RH, Jensen C, Hansen K. Individual and work-related risk factors associated with symptoms of musculoskeletal complaints. Int Arch Occup Environ Health 1993; 64:405–13.
2. Vasseljen O, Westgaard RH, Larsen S. A case-control study of psychological and psychosocial risk factors for shoulder and neck pain at the workplace. Int Arch Occup Environ Health 1995;66:375–82.
3. Vasseljen O, Holte KA, Westgaard RH. Shoulder and neck complaints in customer relations: individual risk factors and perceived exposures at work. Ergonomics 2001;44:355–72.
4. Theorell T, Harms-Ringdahl K, Ahlberg-Hultén G, Westin B. Psychosocial job factors and symptoms from the locomotor system—a multicausal analysis. Scand J Rehabil Med 1991; 23:165–73.
5. Lundberg U, Elfsberg Dohns I, Melin B, Sandsjö L, Palmerud G, Kadefors R, et al. Psychophysiological stress responses, muscle tension, and neck and shoulder pain among supermarket cashiers. J Occup Health Psychol 1999;4:245–55.
6. Rissén D, Melin B, Sandsjö L, Dohns I, Lundberg U. Surface EMG and psychophysiological stress reactions in women during repetitive work. Eur J Appl Physiol 2000;83:215–22.
7. Vasseljen O, Westgaard RH. Can stress-related shoulder and neck pain develop independently of muscle activity? Pain 1996;64:221–30.
8. Westgaard RH, Vasseljen O, Holte KA. Trapezius muscle activity as a risk indicator for shoulder and neck pain in female service workers with low biomechanical exposure. Ergonomics 2001;44:339–53.
9. Holte KA, Westgaard RH. Further studies of shoulder and neck pain and exposures in customer service work with low biomechanical demands. Ergonomics. 2002;45:887–909.
10. Holte KA, Westgaard RH. Daytime trapezius muscle activity and shoulder-neck pain of service workers with work stress and low biomechanical exposure. Am J Ind Med 2002;41: 393–405.
11. Westgaard RH, Bonato P, Holte KA. Low-frequency oscillations (<0.3 Hz) in the electromyographic (EMG) activity of the human trapezius muscle during sleep. J Neurophysiol 2002;88:1177–84.
12. Yin RK. Case study research: design and methods. 2nd ed. London: Sage Publications; 1994.

13. Eysenck HJ, Eysenck SBG. Manual of the Eysenck personality questionnaire, London: Hodder and Stoughton; 1981.
14. Borg G. Psychophysical scaling with applications in physical work and the perception of exertion. Scand J Work Environ Health 1990;16 Suppl 1:55–8.
15. Strauss A, Corbin J. Basics of qualitative research. London: Sage Publications; 1990.
16. Jensen C, Vasseljen O, Westgaard RH. The influence of electrode position on bipolar surface electromyogram recordings of the upper trapezius muscle. Eur J Appl Physiol 1993;67:266–73.
17. Jensen C, Vasseljen O, Westgaard RH. Estimating maximal EMG amplitude for the trapezius muscle: on the optimization of experimental procedure and electrode placement for improved reliability and increased signal amplitude. J Electromyograph Kinesiol 1996;6:51–8.
18. Jonsson B. Kinesiology. With special reference to electromyographic kinesiology. In: Cobb WA, Van Duijn H, editors. Contemporary clinical neurophysiology Amsterdam: Elsevier; 1978. p 417–28. EEG supplement, no 34.
19. Veiersted KB, Westgaard RH, Andersen P. Pattern of muscle activity during sterotyped work and its relation to muscle pain. Int Arch Occup Environ Health 1990;62:31–41.
20. Westgaard RH, Winkel J. Ergonomic intervention research for improved musculoskeletal health: a critical review. Int J Ind Erg 1997;20:463–500.
21. Levine S, Ursin H. What is stress? In: Brown MR, Koob GF, Rivier C, editors. Stress: neurobiology and neuroendocrinology. New York (NY): Marcel Dekker; 1991:1–21.
22. Eriksen HR, Ursin H. Subjective health complaints: is coping more important than control? Work Stress 1999;13:238–52.
23. Jacobson E. Electrical measurements of neuromuscular states during mental activities. VII. Imagination, recollection and abstract thinking involving the speech musculature. Am J Physiol 1931;97:200–9.
24. Holmes TH, Wolff HG. Life situations, emotions, and backache. Psychosom Med 1952;14:18–33.
25. Sainsbury P, Gibson JG. Symptoms of anxiety and tension and the accompanying physiological changes in the muscular system. J Neurol Neurosurg Psychiatry 1954;17:216–24.
26. Weber A, Fussler C, O'Hanlon JF, Grierer R, Grandjean E. Psychophysiological effects of repetitive tasks. Ergonomics 1980;23:1033–46.
27. Westgaard RH, Bjørklund R. Generation of muscle tension additional to postural muscle load. Ergonomics 1987;30:911–23.
28. Wærsted M, Bjørklund RA, Westgaard RH. The effect of motivation on shoulder-muscle tension in attention-demanding tasks. Ergonomics 1994;37:363–76.
29. Hägg GM. Static work loads and occupational myalgia—a new explanation model. In: Anderson PA, Hobart DJ, Danoff JV, editors. Electromyographical kinesiology. Amsterdam: Elsevier; 1991:141–3.
30. Knardahl S. Psychophysiological mechanisms of pain in computer work: the blood vessel-nociceptor interaction hypothesis. Work Stress 2002;16:179–89.
31. Wærsted M, Eken T, Westgaard RH. Activity of single motor units in attention-demanding tasks: firing pattern in the human trapezius muscle. Eur J Appl Physiol 1996;72:323–9.
32. Bansevicius D, Westgaard RH, Jensen C. Mental stress of long duration: EMG activity, perceived tension, fatigue, and pain development in pain-free subjects. Headache 1997; 37:499–510.
33. Larsson R, Öberg PÅ, Larsson S-E. Changes of trapezius muscle blood flow and electromyography in chronic neck pain due to trapezius myalgia. Pain 1999;79:45–50.
34. Steptoe A. Job control, perceptions of control, and cardiovascular activity: an analysis of ambulatory measures collected over the working day. J Psychosom Res 2001;50:57–63.
35. Hubbard DR, Berkoff GM. Myofascial trigger points show spontaneous needle EMG activity. Spine 1993;18:1803–7.
36. Ursin H, Olff M. Psychobiology of coping and defence. Neuropsychobiology 1993;28:66–71.
37. McEwen BS. Stress and the individual. Arch Intern Med 1993;153:2093–101.
38. McEwen BS. Protective and damaging effects of stress mediators. New Engl J Med 1998;338:171–9.
39. Steptoe A. The links between stress and illness. J Psychosom Res 1991;35:633–44.
40. Viikari-Juntura E, Riihimäki H. New avenues in research on musculoskeletal disorders. Scand J Work Environ Health 1999;25:564–8.
41. Griffiths A. Organizational interventions. Facing the limits of the natural science paradigm. Scand J Work Environ Health 1999;25:589–96.

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