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The Relation between Stress, Muscle Activity, and Shoulder/Neck Pain: a Long-Term Field Study on Health Care Workers

BEV3901 Master Thesis
Department of Human Movement Science
Norwegian University of Science and Technology
Trondheim, spring 2011

Acknowledgements

I would like to thank my supervisor Paul Jarle Mork at the Department of Human Movement Science, NTNU, for valuable support and guidance throughout the work with this thesis. Also, I would like to thank my co-supervisor Rolf H. Westgaard for assistance with the study design and recruitment of subjects. Further on, I would like to thank my fellow student Roar Davidsen for the collaboration during the data collection, and the health care workers participating in the project. Finally, I would like to thank my fellow students for many interesting discussions and good times, both on and of campus.

Abstract

Background

Shoulder and neck pain (SNP) is one of the main causes for sick-leave, and the high prevalence affects occupations with both high, moderate and low workloads. At present, the knowledge about pain mechanisms in occupations with low physical workload is still limited. The main purpose of this study was to investigate whether perceived work stress during the workday is related to trapezius muscle activity. A second objective was to investiagte whether trapezius activity differs between individuals with long-term SNP.

Methods

Twenty-seven female health care workers participated. Surface electromyography (sEMG) was recorded from the trapezius muscle throughout the workday. Simultaneous inclinometer recordings of the thigh was used to identify periods with sitting, standing, and walking. SNP and stress were recorded by visual analogue scale and physical fatigue by Borgs scale every hour throughout the workday. An index for long-term SNP was also calculated.

Findings

Two main comparisons were performed: A between group comparison where sEMG in pain-afflicted workers was compared to sEMG recorded from pain-free workers, and an intra-individual comparison where sEMG in periods of high stress was compared to periods of low stress. In the analyses of the sEMG activity pattern, the focus was on median amplitude and rest time defined as activity < 0.5% of the maximal sEMG response. Overall, there was no evidence of a difference in sEMG activity between pain-free and pain-afflicted workers. Neither did sEMG activity differ between periods with high vs. low stress.

Interpretation

The current study does not support the hypothesis that SNP is related to stress-induced low level muscle activity. Further research is needed to reveal the relation between stress, muscle activity and SNP, and the mechanisms behind.

Introduction

Work related shoulder/neck pain (SNP) is a common complaint among workers in the western world with a prevalence of about 30% in the general adult population (Norwegian Institute of Public Health 2010). In addition to reduced health for the afflicted individuals, SNP is also one of the main causes for sick-leave from work (Norwegian Institute of Public Health 2010). The prevalence of muskuloskeletal pain is high, not only for groups exposed to heavy physical workloads (Boschman et al. 2011), but also for workers with low and moderate workload (Sillanpää et al. 2003). Moreover, such complaints are more frequent among women than men, and is especially evident for SNP (Ihlebæk et al. 2002). Prevalence of 31% to 60% for SNP have been reported for health care workers (Ando et. al. 2000; Lagerström et al. 1995)

An often cited hypothesis to explain muscle pain development is the Cinderella hypothesis (Hägg 1991). According to Hennemans size principle, motor units are recruited as a function of motorneuron size (Henneman et al. 1965). In other words, with increasing demand for force development, motor units are recruited from smallest (low treshold) to largest (high treshold). The Cinderella hypothesis proposes that the low threshold motor units are constantly activated during low-level static work, increasing risk of metabolic overload which may cause damage to the muscle cells (Hägg 1991). Although the low threshold motor units are assumed to be fatigue-resistent, there is likely to be an upper tolerance limit for continous firing. Moreover, it is generally believed that work stress may impose additional muscle activiation. In particular, the trapezius muscle has been shown to be responsive to stress (Wærsted and Westgaard 1996).

In support of the Cinderella hypothesis is the findings of abnormalities in isolated muscle fibers, e.g., moth eaten fibers and ragged red fibers (Hägg 2000). These muscle fibers shows disrupted mitochondrial activity which is a likely sign of an “energy crisis” due to sustained activation. Animal experimental research has clearly shown that low-intensity loading can lead to muscle damage, given that the muscle activation is sustained over time (Lexell et al. 1993). In humans, findings of muscle cell abnormalities are common in the trapezius muscle, which also is a common location of neck and shoulder pain (Kadi el al. 1998)

As a continuation of the Cinderella hypothesis, the Ca2+ accumulation theory aim to explain how pain may arise in the overloaded muscle cells. The sustained low-level muscle activation may lead to increased Ca2+ accumulation within the muscle cell. The Ca2+ may in turn activate the neural protease calpain which may cause degradation of membrane proteines, causing leakage of the intracellular enzyme lactate dehydrogenase. Membrane leakages are likely to result in stimulation of nociceptors and thereby the sensation of muscle pain (Gissel 2000).

Surface electromyography (sEMG) is the detection and recording of the electrical signal that emanates from the contracting skeletal muscles (De Luca 2006). This method of recording muscle activity is a method frequently used to study the relation between trapezius muscle activity and SNP (Mathiassen et al. 1995). Investigations of SNP in workers with focus on trapezius sEMG recordings include both laboratory, short-term and long-term field studies. Most of the laboratory and short term field studies include sEMG recordings during standarized tasks like typing and use of computer mouse; however, other occupational tasks are also represented. Although useful information about different factors that may affect muscle activation can be obtained from controlled laboratory studies and short-term field recordings, it is uncertain whether the recordings are representative of ”real-life” muscle activation patterns. Thus, some studies have attempted to investigate whether the observations made in the laboratory can be translated to a field setting, regarding the relation between SNP and muscle activity.

Østenvik and co-workers (2009a and 2009b) found that forest workers with longer periods of sustained low-level trapezius muscle activity had increased risk of developing SNP. Sjörs and co-workers (2009) reported higher trapezius activity in women with trapezius myalgia during uninstructed rest, while Szeto and co-workers (2005) found a strong correlation between trapezius activity and SNP when they devided the pain-afflicted group in “low discomfort” and “high discomfort” groups. Other studies have reported non-significant trends toward a relation between SNP and trapezius sEMG recordings (Holte and Westgaard 2002; Szeto et al. 2009; Voerman et al. 2007), while Strøm and co-workers (2009) and Rissén and co-workers (2000) found no significant associations between trapezius activity and SNP.

The Malmö shoulder and neck study cohort showed that job stress was the factor most strongly associated with the development of SNP in women (Östergren et. al. 2005). Several studies have also reported significant correlations between negative stress/ percieved general tension and trapezius sEMG (Larsman et al. 2009; Rissén et al. 2000, Vasseljen and Westgaard 1995).

Except for the one study conducted on forest workers (Østenvik et al. 2009a, 2009b) the studies mentioned examining sEMG investigated groups with low workload (i.e., office workers and cashiers). This does not represent the level of workload brought upon health care workers, exposed to physical demands, alternating from low to moderate to high during the workday. At present, there is a lack of field studies examining the impact of the mentioned alternating workload on muscle activity and SNP. In addition to the alternating physical demands, health care workers are also frequently exposed to high levels of work stress. Therefore, it is relevant to investigate work stress as a possible contributor in the development of SNP.

The aim of this study was to investigate whether perceived work stress during the workday is related to trapezius muscle activity.Work stress and percieved general tension were recorded every hour throughout the workday along with sEMG recordings of the trapezius muscle. A second objective was to investiagte whether trapezius activity differs between individuals with long-term SNP.

Materials and Methods

Workers

Twenty-seven female health care workers (mean age 35.7, SD ±11.1, range 21 - 58), from Trondheim, Norway, were recruited to participate in the study. Workers with any of the following conditions were excluded from the study; rheumatism, heart disease, endocrine/metabolic diseases, other chronic disease e.g., Parkinson's, stroke, and pregnancy. All participants gave a written informed consent prior to participation. The study protocol was approved by the Regional committee of Medical Research Ethics and carried out according to the declaration of Helsinki.

Work description

The health care workers operate individually, attending to elderly and disabled clients in their homes. One of the main inclusion criteria's was the title ”primary contact”, which implies the main responsibility for at least one patient. The health care workers tasks include patient handling (e.g., dressing, treatment of wounds/injuries, administering medications, assisting personal hygiene, eating, and walking) and patient activation (both physical and mental). The physical workload varies between clients and tasks, with occasional lifting. The health care workers operate according to a tight schedule, allowing only prescribed services to the patients.

Table 1. Percentage of employment, age, BMI and pain index score for the health care workers.

Variables	
Percentage of employment	94 ± 8.5 (75 – 100)
Age	36 ± 12 (21 – 58)
BMI	24 ± 2.7 (20 – 29)
Pain Index Score	2 ± 1.7 (0 – 5)

Values are mean ± SD, with range in parentheses.

Study protocol

The study was carried out with a cross-sectional design. Between-group comparisons were used to investigate differences in sEMG between pain-afflicted vs. pain-free workers. Within-subject comparisons were used to assess intra-individual differences in sEMG in periods of low and high stress. Long term field recordings of muscle activity and heart rate were carried out along with hourly subjective recordings of pain, work stress, and fatigue. Just before and just after the field recordings a number of laboratory tests were carried out, including testing of pressure pain threshold (PPT) and maximal voluntary contractions (MVC). The workers also responded to a more comprehensive questionnaire that included information about general background and pain status.

Pressure pain threshold (PPT)

An electronic pressure algometer (Somedic ® Algometer type 2, Sweden) was used to record the PPT at the central muscle belly of the descending trapezius. The probe of the algometer had a diameter of 10 mm, and the applied pressure slope was 40 kPa/sec. The location used was 2 cm medially of the midpoint between the 7^{th} cervical vertebrae (C7) and the lateral edge of the acromion, i.e., corresponding to the placement of the sEMG electrode for the descending trapezius (see below). Pressure readings were conducted three times on both right and left trapezius, with approximately 30 sec between each trial. During testing, the subject sat erect, with the back towards the back rest of the chair, and with arms resting in the lap. The workers were informed to express when she the applied pressure changed from a sensation of pressure to being painful. Thus, the PPT device establishes absolute pressure at pain threshold. A mean of the three recordings was used in further analysis.

Physiological recordings

During the long-term workday field recording, the workers were instructed to carry out all the normal tasks and duties. A portable recording system (Myomonitor IV, Delsys Inc., Boston, USA) was used to record trapezius sEMG, postural angles from one arm and leg, and electrocardiography (ECG). All data were sampled at 1000Hz, and stored on a memory card for off-line analyses. The data logger was carried in a waist bag during the recordings.

sEMG activity was recorded bilaterally from the descending trapezius and from the right hand side from the transverse and ascending trapezius. Bipolar surface bar electrodes with an inter-electrode distance of 20 mm (length 10 mm, diameter 1 mm) was used to record muscle activity (Delsys Inc., Boston, USA). Adhesive sensor interfaces were attached to the electrodes. For the descending trapezius, the EMG electrodes were placed 2 cm medially to the midpoint between C7 and the lateral edge of the acromion. For the transverse subdivision, the electrode was placed on the midpoint between the medial border of the scapulae and the 4th thoracic vertebra. For the ascending subdivision the electrode was placed on the midpoint between the medial scapular border and the 8th thoracic vertebra. All electrodes were placed parallel to record muscle action potentials propagating in the supposed fiber direction. A reference electrode was placed at C7.

Heart rate was recorded by two ECG-electrodes (Red Dot™, 3M, Neuss, Germany), positioned on the claviculae and the 9th rib on the left side. Before application of the EMG-, ECG- and reference electrode, the surface area was cleansed by rubbing the skin with red spirit- induced cotton.

A 2D inclinometer (Delsys Inc., Boston, USA) was used to record postural angles of the left thigh. The thigh inclinometer was placed mid way between the lateral knee epicondyle and trochantor major, positioned to record movements in the sagittal plane (i.e., hip flexion/extension).

Calibration

The sEMG responses during the long-term recordings were normalized relative to the maximal sEMG response (sEMGmax) obtained during maximal voluntary contractions (MVCs). The workers performed two isometric MVCs for the descending, transverse, and ascending trapezius muscle, while seated on a chair. The subject was instructed to maintain an erect seated posture with both arms 90 degrees abducted in the scapular plane, with resistance applied just proximal to the elbow joint. To assess the descending trapezius sEMGmax, the resistance applied was a strap attached to the floor. To assess maximal force, a force transducer (SM-200N Interface, Kissler, Arizona, USA) was included as a link between the floor and the strap on the right hand side. To determine the sEMGmax for the transverse and ascending trapezius, the resistance was applied at the posterior and superior side of the arm, respectively. Maximal voluntary contractions were held for approximate 3 sec, separated by 1-min pauses. Verbal encouragement was given by the experimenter for all calibration trials. Force data (Newton) was recorded synchronous to the MVCs (Force not reported here). The highest sEMG response was used to normalize the sEMG signal.

sEMG and ECG analyses

sEMG signal was digitally band-pass filtered (10-450 Hz, Butterworth, 6th order) and the signal was then root-mean-squared (RMS; 100 ms window, no overlap) and stored with a time resolution of 0.1 sec. The sEMG noise level was made equal to the minimum level of visually detected sEMG activity during the long-term recordings, and subtracted from the RMS signal when quantifying the sEMG responses. sEMG activity during periods of walking, standing, sitting, and a combined stand/walk category was extracted from the long-term recordings. Outcome variables were median sEMG level (% EMGmax) and the muscle rest time defined as duration below sEMG activity of 0.5% EMGmax.

Due to technical problems concerning the battery capacity of the portable recording systems, the recordings lasted from 0 to 6.5 hours. This problem reduced the number of applicable recordings available for analysis from 27 to 20, as this report only includes recordings $\geq$ 2.5 h.

Posture analyses

Figure 1 illustrates the detection of the four posture categories standing, walking, sitting, and the combined stand/walk relied on visual inspection of an amplitude/time display of the recordings from the thigh inclinometer.

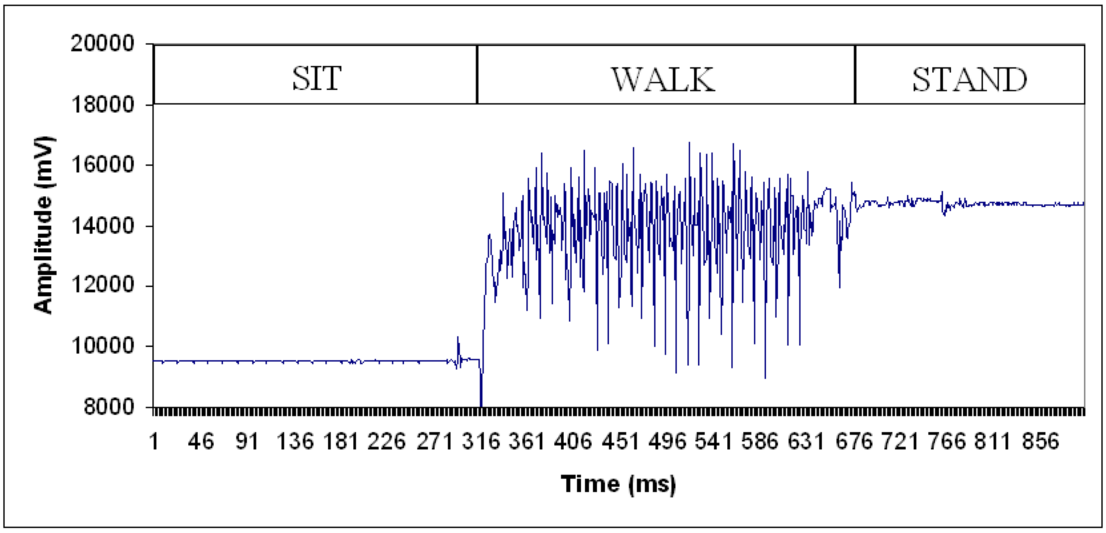

Figure 1. Illustration of the visual display of an inclinometer thigh recording for manual analysis.

Subjective variables

Every hour throughout work, the workers scored their level of SNP, low back pain (not reported here), perceived stress, and physical fatigue. Except for physical fatigue, scoring of intensity was performed on a 10-cm visual analogue scale (VAS) with end points ”very low” and ”very high”. In the case of pain, workers first checked off whether they had pain at all. Physical fatigue was scored on Borg’s scale (Borg 1990). In addition, the workers responded to an extended version of the questionnaires described above, at the beginning and end of the work day. The extended version included VAS recordings of headache, pain in the hand, wrist, elbow, hip, knee, feet, and the possibility to fill in any pain not described in the standardized questions.

All workers also responded to a more comprehensive questionnaire. This included information about biographic data (age, weight, height, number of children), general health (exercise, sleep, level of pain in distinct parts of the body over the last twenty-four hours/last week/last 6-month period), psychological profile, previous jobs, current workload, and general psychosocial stress factors (off-work duties, personal economy, family situation).

A pain index ranging from 1 to 6 based on the workers score on intensity and frequency was applied to categorize the workers as pain-afflicted or pain-free. A study by Westgaard and Jansen (1992) using the same pain index found that a score of 3 represented a 45% chance of seeking medical consultation due to the pain. Therefore, a cut-off score of 3 was chosen in this report. The "Pain"-group consisted of 8 workers scoring ≥ 3, the remaining 12 workers constituted the "No Pain"-group as they scored ≤ 2 on the pain index.

VAS score on stress was used to select periods during the day with high and low stress. Seven recordings contained the hours scored by the subject as "high stress" (mean 53.3) and "low stress" (mean 8.4) as the minimum difference between high and low stress was set to 20 units (20 mm on the 100 mm long VAS scale).

Statistical Analyses

The software package SPSS for Windows 18.0 was used for all statistical analyses, except calculating the confidence interval (95%) where NCSS 6.0 was utilized. Nonparametric statistical methods were used for comparison of variables with non-normal distributions. The Wilcoxon signed-rank test was applied to test the hypothesis that subjective scores (stress) and sEMG activity did not differ between high and low stress periods. A Mann-Whitney U-test was used to test differences between independent groups (pain-afflicted vs. pain-free workers). For the normally distributed variables (i.e., heart rate) a paired samples t-test was used to test differences from before work to the last hour of work, while an independent samples t-test was used for group comparisons. A bivariate correlation analysis was used to test the relationship between the change in PPT and sEMG. A probability level of $p < 0.05$ was considered to indicate significant differences. Data are reported as mean ± SD and median with 95% CI.

Results

Body Posture

Table 1 presents the relative time (% of total recording time) spent in different postures. The average recording time was 4.5 hours. Periods of walking interrupted by shorter periods of standing (< 5 sec) were classified as ”stand+walk”. On average, the workers spent ~ 60% of the day in either standing or walking. Note that as a part of the daily routines, the health care workers attended a morning assembly when commencing the workday. The assembly lasting approximately 0.5 hours, greatly contributes to the relative time in seated position, especially for the recordings of shorter duration.

Table 2. Relative time (% of total recording time) spent in different postures.

Posture	
Sit	39.3±12.8
Stand	14.5 ±5.0
Walk	32.6 ±10.0
Stand+Walk	13.6 ±4.7

Values are mean ±SD

Perceived work stress

Figure 2 shows hourly subjective scores of physical fatigue (A) and perceived work stress (B) during the workday.

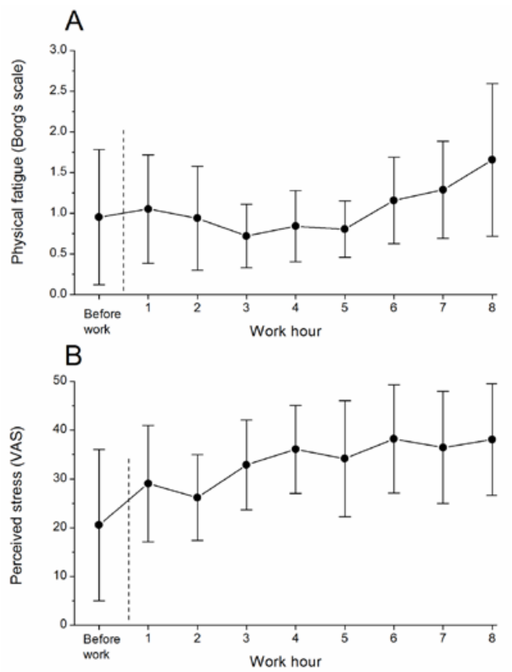

Figure 2. Illustration of the change in physical fatigue (A) and perceived stress (B) during the workday. Values are mean with 95% CI. The dotted line represents start of work.

There was no difference in physical fatigue from before work to the last hour of work (p = 0.35). Mean fatigue scores for the hour before work was 1.0 and for the last hour of work 1.7 on Borgs scale, where 1 is decribed as “very weak” and 2 as “weak”. The mean score for percieved stress was 20.5 before work and increased significantly with a mean score of 38.1 for the last hour of work (p = 0.008).

Table 3. Heart rate (beats/min) in periods with high and low stress.

Posture	High stress	Low stress	p*
Sit	82.1 ±6.5	78.4 ±4.4	0.21
Stand	88.1 ±4.8	83.1 ±7.5	0.16
Walk	88.9 ±5.1	83.6 ±8.8	0.17

Values are mean±SD * paired t-test

Table 3 display heart rate in the high stress and low stress periods during sitting, standing, and walking. The lowest heart rate was observed when the workers were sitting, following was heart rate during standing, and a slightly higher heart rate during walking. There was no significant difference between high and low stress periods, but mean heart rate was slightly higher during high stress compared to low stress.

Table 4. Median sEMG activity in high stress and low stress periods.

	High stress	Low stress	p*
Sit			
R trap desc	1.3 (0.6 – 3.5)	2.5 (0.8 – 3.4)	0.26
R trap transv	1.8 (0.8 – 2.6)	1.8 (1.3 – 2.3)	1.00
R trap asc	2.1 (0.9 – 4.1)	2.1 (1.3 – 2.5)	0.78
L trap desc	2.1 (0.8 – 3.2)	2.3 (0.9 – 3.3)	0.40
Stand			
R trap desc	3.8 (0.9 – 6.1)	3.7 (0.9 – 6.1)	0.89
R trap transv	3.1 (1.2 – 4.7)	3.7 (0.8 – 5.4)	1.00
R trap asc	3.4 (1.3 – 4.2)	3.3 (1.0 – 7.5)	0.89
L trap desc	3.7 (1.1 – 4.5)	3.1 (0.9 – 5.2)	1.00
Walk			
R trap desc	4.8 (0.8 – 7.6)	4.9 (1.5 – 9.0)	0.40
R trap transv	5.9 (2.9 – 9.3)	6.2 (3.2 – 9.7)	1.00
R trap asc	5.4 (1.9 – 10)	5.5 (3.6 – 8.2)	0.48
L trap desc	5.9 (1.7 – 7.7)	5.7 (3.0 – 6.4)	0.89

Values are median (95% CI) *Wilcoxon signed rank test

Table 4 and 5 shows group median sEMG and rest time, respectively, for sitting, standing, and walking during high stress and low stress periods. sEMG activity was lowest during sitting and highest during walking, with standing in between. There was no significant difference in the sEMG activity between the periods categorized as high versus low stress, respectively (p>0.12 for both median sEMG level and muscle rest time).

Table 5. Rest time (%) in high stress and low stress periods.

	High stress	Low stress	p*
Sit			
R trap desc	32 (0.6 – 49)	26 (3.4 – 39)	0.20
R trap transv	12 (0.2 – 28)	9.3 (1.7 – 36)	0.48
R trap asc	12 (0.6 – 27)	12 (4.3 - 22)	0.89
L trap desc	33 (6.9 – 44)	32 (1.8 – 45)	0.78
Stand			
R trap desc	9.3 (0.4 – 32.3)	15 (0.0 – 31)	0.35
R trap transv	8.7 (0.0 – 24)	12 (0.0 – 19)	0.87
R trap asc	4.9 (0.0 – 16)	11 (.0 – 15)	0.87
L trap desc	7.3 (0.9 – 19)	9.2 (0.3 – 21.8)	0.26
Walk			
R trap desc	3.3 (0.5 – 10.8)	6.1 (0.0 – 9.3)	0.58
R trap transv	0.7 (0.0 – 13.7)	2.7 (0.0 – 11)	0.89
R trap asc	0.3 (0.0 – 2.3)	1.0 (0.0 – 4.9)	0.35
L trap desc	3.4 (0.6 – 21)	2.8 (0.7 – 7.8)	0.12

Values are median (95% CI) *Wilcoxon matched-pair test

Shoulder and neck pain

Figure 3 shows hourly scores of SNP during the workday among pain-afflicted and pain-free workers (i.e., divided by a cut-off score of ≥3 on pain index for pain-afflicted workers). For VAS scores of SNP, the pain-afflicted subjects scored 30.6 before work and 30.0 in the last hour of work, while the pain-free subjects scored 3.6 before work and 8.7 in the last hour of work. The difference in pain score from before to after work was not significant (p>0.70) for pain-afflicted and pain-free workers.

Bivariate correlation analysis between sEMG for the upper trapezius, and difference in mean PPT from before work til after work gave no assocation (p > 0.237 for all associations).

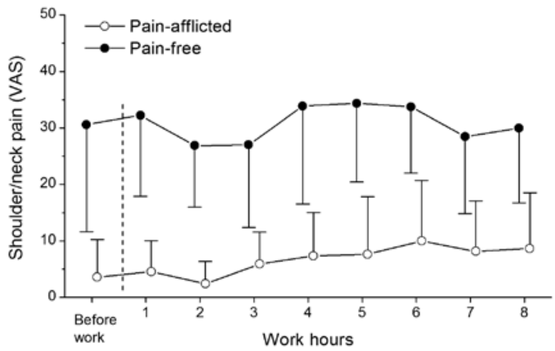

Figure 3. VAS scores of SNP during the workday for pain-afflicted and pain-free workers. Values are mean with 95% CI. The dotted line represents the start of work.

Table 6 present heart rate in the pain-afflicted and pain-free group during sitting, standing and walking (divided by pain index). The lowest heart rate was observed when the workers were sitting, following was heart rate during standing, and the highest heart rate was observed during walking. There was a significant higher heart rate in the pain-free workers compared to the pain-afflicted workers during sitting and walking, and a non-significant trend during standing. However, when heart rate was converted into percentage of maximal heart rate, based on the age predicted heart rate of each worker (220 – age), the pain-afflicted workers had a significantly higher heart rate compared to the pain-free workers for all postures ($p<0.045$ for all comparisons).

Table 6. Heart rate (beats/min) in the pain-afflicted and pain-free workers.

	Pain	No pain	p*
Sit	78.5 ±8.0	86.7 ±6.9	0.01
Stand	83.4 ±9.3	90.5 ±5.3	0.06
Walk	84.9 ±8.6	92.7 ±6.2	0.04

Values are mean ±SD *independent samples t-test

Table 7 and 8 shows group median sEMG among pain-afflicted and pain-free workers (divided by pain index) for sitting, standing, and walking during working hours. sEMG activity was lowest during sitting and highest during walking. Accordingly, this difference is reversed when examining rest time, i.e., rest time was lowest during walking, and highest during sitting.

Table 7. Median sEMG activity in pain-afflicted and pain-free workers.

	Pain	No pain	p*
Sit			
R trap desc	3.3 (0.9 – 3.5)	1.5 (0.7 – 3.1)	0.79
R trap transv	1.5 (1.0 – 1.9)	1.9 (0.8 – 3.2)	0.09
R trap asc	2.3 (1.6 – 3.9)	1.5 (0.6 – 4.0)	0.03
L trap desc	3.3 (1.7 – 4.5)	2.4 (0.8 - 3.5)	0.18
Stand			
R trap desc	4.2 (1.0 – 5.7)	3.3 (0.7 – 5.3)	0.55
R trap transv	2.1 (1.0 – 3.8)	1.8 (0.8 – 4.8)	0.91
R trap asc	2.9 (1.8 – 4.7)	1.3 (0.8 – 3.9)	0.19
L trap desc	4.1 (1.6 – 5.5)	2.8 (0.9 – 3.9)	0.16
Walk			
R trap desc	4.9 (3.3 – 7.4)	5.1 (1.8 – 6.7)	0.82
R trap transv	5.4 (2.9 – 8.1)	6.0 (3.5 – 9.5)	0.59
R trap asc	6.3 (3.1 – 9.6)	4.0 (1.3 – 9.0)	0.12
L trap desc	6.0 (3.1 – 7.2)	4.9 (3.8 – 5.6)	0.23

Values are median (95% CI) * Mann-Whitney u-test

Overall, there was no significant difference in the median sEMG activity between pain-afflicted and pain-free workers, except for higher activity among pain-afflicted workers in the right ascending trapezius during sitting (p = 0.03).

Table 8. Rest time (%) in pain-afflicted and pain-free workers.

	Pain	No pain	P*
Sit			
R trap desc	37 (13 – 45)	36 (16 – 63)	0.48
R trap transv	45 (16 – 60)	19 (5.7 – 35)	0.07
R trap asc	31 (7.2 – 56)	27 (4.8 – 57)	0.97
L trap desc	29 (14 – 42)	33 (16 – 40)	0.87
Stand			
R trap desc	18 (9.3 – 3.5)	21 (7.8 – 57)	0.92
R trap transv	33 (8.9 – 46)	18 (0 – 57)	0.31
R trap asc	18 (5.1 – 33)	21 (0.1 – 45)	0.97
L trap desc	17 (5.4 – 28)	16 (6.5 – 43)	0.62
Walk			
R trap desc	6.9 (1.5 – 28)	6.4 (3.3 – 27)	0.82
R trap transv	4.3 (0.5 – 21)	3.2 (0 – 16)	0.39
R trap asc	2.8 (0.3 – 8.5)	2.1 (0 – 13)	0.97
L trap desc	5.4 (1.3 – 15)	4.2 (3 – 21)	0.66

Values are median (95% CI) * Mann-Whitney u-test

Conversely, median sEMG activity tended to be lower in pain-afflicted workers for the transverse trapezius. However, this difference did not reach significance (p = 0.088). When examining the difference between rest time in pain-afflicted and pain-free workers, there was no significant differences between the two groups of workers. However, there was a non-significant trend towards a higher rest time in the right transverse trapezius, in pain-afflicted workers during sitting ($p = 0.070$).

Discussion

The main purpose of this study was to investigate whether perceived work stress during the workday is related to trapezius muscle activity. A second objective was to investiagte whether trapezius activity differs between individuals with long-term SNP. Data was obtained by long-term sEMG field recordings. Two main comparisons were performed: A between group comparison where sEMG in pain-afflicted workers was compared to sEMG recorded from pain-free workers, and an intra-individual comparison where sEMG in periods of high stress was compared to periods of low stress. In the analyses of the sEMG activity pattern, the focus was on median amplitude and rest time defined as activity < 0.5% of the maximal sEMG response. Overall, there was no evidence of a difference in sEMG activity between pain-free and pain-afflicted workers. Neither did sEMG activity differ between periods with high vs. low stress.

Workload

Percentage of workday in upright posture is higher than a previous study by Mork and Westgaard (2007) conducted on secretaries, call-center operators and help-desk workers (24±12%, 14 ±2.9% and 17 ±11% respectively, vs. 60%). That is, health care workers appear to have a higher physical workload compared with other occupations with high SNP prevalence. However, the health care workers experienced the same level of physical fatigue (1.5 vs. 1.1 on Borg's scale) as the occupations mentioned (Mork and Westgaard 2005). This indicates that despite the high percentage in upright posture, the physical workload was perceived as low.

While physical fatigue remains unchanged throughout the day, stress increased significantly (from 20.5 to 38.1 VAS units), in consistency with other long-term studies of health care workers and groups with low biomechanical exposure (Holte and Westgaard 2002a, Westgaard et al. 2001). Thus, stress appears to be associated with exposures at work.

Perceived work stress

As laboratory studies reports increased heart rate as a response to stress (Fechir et al. 2008; Kristiansen et. al. 2009), there was expected a higher heart rate in periods with high perceived stress compared to periods with low perceived stress. A long-term field study by Holte and Westgaard (2002b) reported a small, but significant increase in heart rate during high stress periods among health care workers. In the current study, such a difference was not observed. However, Nilsen and colleagues (2007) demonstrated that during a stress task lasting 60 min, heart rate first increases rapidly, then decreases slowly during the course of the stress test, approaching baseline at the end. Thus, the significantly increased heart rate, demonstrated in shorter laboratory trials as an immediate reaction to stress tasks, may not be apparent when examining longer periods with stress. In other words, this may indicate that health care workers in the current study habituate their physiological stress responses to the external stress exposure.

The lack of differences between muscle activity in periods of high vs. low stress in this and previos studies (Holte and Westgaard 2002b; Mork and Westgaard 2007) is in conflict with findings of increased muscle activity demonstrated in response to mental stressors in laboratory experiments (Larsman et al. 2009). Also studies conducted in field comparing high and low stress periods reported significant differences in muscle activity (Rissén et al. 2000; Vasseljen and Westgaard 1995). However, laboratory studies exposing subjects to more than one stress task, obtained different results for each test (Fechir et al. 2008; Kristiansen et. al. 2009). There might be several possible reasons for these conflicting findings. First, the periods classified as high stress might not be of sufficient intensity, indicating that a minimum stress intensity is required to increase trapezius muscle activity. Second, while these studies compare groups, individuals have different abilites to cope with stress despite apparent similar stress exposures (Eriksen et al. 1999). That is, subjective measurements of perceived stress might not be optimal to reflect responses in the body. Furthermore, as mentioned in relation to heart rate, the time dimention also appears to be relevant. Individual conditions determines the duration of stress responses such as increased brain activity, increased heart rate and secretion of stress hormones. (Eriksen et al. 1999; Nilsen et al. 2007). Finally, the lack of relation between stress and muscle activity observed in this study is consistent with a proposed alternative pathway between stress and SNP development, excluding muscle activity. As secretion of stress hormones to the blood is a response to stress (Lundberg et al. 1999), it is suggested that the catabolic effect of cortisol may cause muscle tissue deterioration, and thereby pain (Sjøgaard et al. 2000). To summarize, no evidence of any difference in trapezius muscle activity between high and low stress periods was found. Thus, stress may play an important role in the pathogenesis of musculoskeletal pain exclusive of muscle activity.

Shoulder and neck pain

There was no difference in SNP between the hour before work and the last hour of work, neither for the pain-afflicted nor the pain-free workers, in contrast with a previous study by Holte and Westgaard (2002a). This might be due to a high morning pain score (30.6 VAS units) for the pain-afflicted workers, which indicates that SNP is not an immediate reaction to exposures at work.

Interestingly, pain-afflicted workers had significantly lower heart rate than the pain-free workers while sitting and walking, and a trend when standing. As maximal heart rate declines with age (Tanaka et. al. 2001), the percentage of maximal heart rate was also calculated based on the age-predicted maximal heart rate. The pain-free workers turned out to have significantly lower heart rate compared to the pain-afflicted. However, the age-predicted maximal heart rate formula most commonly used (220 – age) has been proven inaccurate (Tanaka et. al. 2001). Also, as physical activity influences stroke volume (Tanaka el.al. 2001), the difference in heart rate may be due to a difference in fitness level, presuming that pain-afflicted individuals practice less physical activity compared to the pain-free individuals due to pain. Alternatively, the lower heart rate may also indicate that pain-afflicted workers restrict their physical workload due to musculoskeletal symptoms.

Except for a higher median activity among pain-afflicted workers in the right ascending trapezius during sitting, there was no significant difference in trapezius activity between pain-afflicted and pain-free workers. Rest time was shortest during walking (>2.1%), while during sitting rest time ranged from 19% to 45%, thus, for both groups, also the lowest threshold motor units benefited from long periods of rest during the workday. Several studies reports significant associations between SNP and trapezius sEMG recordings (Mork and Westgaard 2006; Sjörs et al. 2009; Szeto et al. 2005; Østenvik at al. 2009a; 2009b). Mork and Westgaard (2006) conducted a comparable long-term field study on females with low biomechanical load. They defined three response categories (low, medium, high) by sEMG activity and found an activity pattern consistent with the low-threshold motor unit overexertion for the high- but not the low-response group. The lack of association between muscle activity and SNP found in this study is consistent with findings by Holte and Westgaard (2002a) and Rissén and colleagues (2000). In other words, the lack of association between SNP and muscle activity is just as easily found as the opposite.

This study, utilizing in total three different measurements of pain (a long-term pain index comprising duration and intensity of pain last 6 months, on acute pain response indicated by hourly VAS scores, and PPT), lacks evidence to support a relation between SNP and muscle activity. However, the sEMG does not record whether low-threshold motor units changes from an irregular activity pattern to a sustained activity pattern, with more metabolic stress on the motor units in use. Further, Mork and Westgaard (2005) reported signs of a motor habit as they found large differences in inter-individual responses and consistency intra-individually. Such a motor habit would make it difficult to detect differences between pain-afflicted and pain-free subjects using group-based comparisons of muscle activity, and it might be deviations from the motor habit that causes pain. Wakefield and colleagues (2010) investigated the effect of acute trapezius pain on habitual trapezius activity during unconstrained daily activities, and found that trapezius activity was accompanied by an elevated median sEMG level in the pain-afflicted upper left trapezius. Several longitudinal studies with repeated measurements are needed to investigate how deviation from a possible motor habit may cause pain.

Study limitations

The main strength of this study lies in its methodological design, a long-term study conducted in field, allowing collection of the subjective and physiological changes, during the time in the environment causing pain. However, there are some limitations that need to be considered in the interpretation of the findings. First, the way the workers were recruited to the study may have introduced a “Healthy worker effect” (Shah 2009). This concern was strengthened by the observation of enrolled workers resigning from the data collection due to sick leaves. In the case of this selection bias, the workers most afflicted by SNP might not be represented in the recordings, possibly reducing the differences between pain-afflicted and pain-free workers.

Second, due to technical problems concerning the battery capacity of the portable recording systems, the number of applicable recordings available for analysis was reduced from 27 to 20. As the obtained data showed no differences between groups, it is highly unlikely that the additional recordings would reveal any other relation.

Further, cross talk is a problem at present when applying the method of sEMG. Pettersen and Westgaard (2005) investigated cross talk between neck muscles, but found no evidence. As groups are compared, for cross talk to be an actual limitation in this report, this bias would have to be dominant in only one of the groups. This is highly unlikely.

Another question is whether the electrodes actually records the muscle activity possibly causing pain. The placement of three electrodes on the right trapezius minimizes the risk of not recording the possible muscle activity causing pain, as they cover the major parts of the muscle.

Concluding remarks

This long-term field study of health care workers may be summarized as follows: The alternating workload did not result in a higher perceived physical fatigue compared to occupations with low biomechanical demands. Perceived stress increased during the workday, presumably due to exposures at work. However, the findings did not support the hypothesis that SNP is related to stress-induced low level muscle activity. Further research is needed to reveal the relation between stress, muscle activity and SNP, and the mechanisms behind.

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