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Upper Trapezius Muscle Activity Pattern at Work and Associated Neck Pain: Study Protocol for Analyses of a Pooled EMG Data Set

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ABSTRACT

Background: Repetitive and monotonous work is often associated with neck pain, potentially resulting in sick leave and reduced productivity. Establishing appropriate muscle activity patterns, including duration and frequency of breaks that can prevent neck pain development, is important for providing workplace guidance. While several smaller studies addressing monotonous neck-loading work have indicated that such breaks can reduce the risk of neck pain, studies with a higher number of participants are necessary to confirm an association, and if so, to improve the precision of a possible association. The purpose of this protocol was to describe and discuss the background, methods, and challenges of a study pooling several datasets with measurements of upper trapezius muscle activity during work and associated measurements of neck pain.

Methods: Seven Scandinavian research institutes provided surface electromyographic (EMG) data from 750 participants of upper trapezius muscle activity recorded during working hours along with questionnaire data containing information about neck pain and other health-related factors. The different EMG datasets were merged into a common format. Various questions on neck pain will be harmonized. Associations between EMG variables and neck pain will be examined using linear mixed model regressions controlled for various confounders.

Discussion: Aiming to provide further insight into the possible association between trapezius muscle activity pattern and neck pain, this study protocol highlights the challenges that arise when creating a pooled data set. Solving these challenges may help increase the knowledge about appropriate muscle activity patterns during work.

Keywords: Musculoskeletal disorders, Work exposure, Electromyography

INTRODUCTION

Neck pain is a common musculoskeletal disorder with several potential negative consequences, not only for an individual's health and well-being but also for productivity, absence due to sickness, and disability (Henschke et al., 2015, Andersen et al., 2011). The causes of neck pain are multifactorial (da Costa and Vieira, 2010), and various forms of biomechanical exposure have been suggested as possible risk factors for neck pain (Andersen et al., 2021).

The upper trapezius muscle activity reflects biomechanical exposures of the neck but can also be influenced by psychosocial exposures, such as the mental or emotional load of the tasks (Wærsted, 2000), stress (Shahidi et al., 2013), general tension, and breaks during work (Samani et al., 2009). In a preventive context, a person's neck activity or activity pattern during work as a risk factor for later neck pain is of interest.

Regarding the mean muscle activity, no consistent correlations with neck pain have been found (Veiersted et al., 1990, Vasseljen and Westgaard, 1995, Røe et al., 2001, Szeto et al., 2005, Strøm et al., 2009, Madeleine, 2010). In general, increased mean muscle activity therefore does not appear to be related to concomitant pain although two larger studies have found such associations (Balogh et al., 2019, Balogh et al., 2016).

On the other hand, muscular rest or the recovery of a muscle during work may be a subject of interest. Cross-sectional field studies have found positive associations (Thorn et al., 2007, Luttmann et al., 2010) in addition to no associations (Nordander et al., 2000, Westgaard et al., 2001) between low levels of muscular rest in the neck muscles and neck pain. Two prospective studies showed that a higher proportion of muscular rest led to a lower risk of developing neck pain (Veiersted et al., 1993, Aarås, 1994). Therefore, a strong indication that short intermittent periods with muscular rest may be important to prevent neck pain is present. Many short work–rest periods thoughout the day were also suggested to cause more muscular recovery than a few long work–rest periods (Dul et al., 1991).

Comparing recommendations of various rest allowance models, a review found substantial discrepancies in the ratio of rest and working time (El Ahrache and Imbeau, 2009). A later review found similar results when comparing different work rest models aiming to calculate a "breakpoint" for which muscle fatigue exceeds the appropriate necessary recovery during working tasks (Neumann et al., 2020). The calculated breakpoints differed considerably depending on work task thus making it difficult to generalize these models to different work tasks.

A more detailed approach for examining the activity–recovery-ratio and its association with neck pain is to examine the muscle activity pattern during work. Previously, periods with sustained low-level muscle activation (SULMA) have been described as periods with no muscular rest and fewer possibilities of recovery. Specifically, SULMA periods have been defined as continuous muscle activity above 0.5% of the electromyographic (EMG) activity obtained during an individual maximal voluntary effort (MVE) with a duration of at least 1.6 s (Østensvik et al., 2009). An increased risk of neck pain in subjects having several SULMA periods with durations > 4 min (Hanvold et al., 2013), or > 8 min (Østensvik et al., 2009) during work could be shown.

Despite many years of research, results concerning the association of trapezius muscle activity and neck pain are not consistent and partially conflicting. Possible reasons for such conflicting results might be that previous studies included different professions and were mostly based on a relatively low number of participants.

The aim of this protocol is to describe and discuss the background, methods, and challenges for the analyses on a pooled dataset from seven Scandinavian research Institutes, including a high number of participants from various professions, to confirm possible associations between trapezius muscle activity during work and neck pain, and if so, to improve the precision of these associations.

Hypotheses

In hypothesis #1, we assume that several indicators of trapezius activity during work are positively associated with neck pain: (1) high median muscular activity during the working day, (2) frequent high peak loads, and (3) sustained muscle activity, also at low exertion levels.

In hypothesis # 2, we expect several indicators to be negatively associated with neck pain: (1) the number of micro-pauses, both in light and heavy work and (2) a high number and total time of periods with no/low muscle activity ("pauses"/"gaps") related to spontaneous or planned breaks. Additionally, we expect that jobs with high muscular load require more pauses to reduce the association with neck pain than those with low muscular load do.

METHODS

The pooled dataset includes anonymized general information, bilateral EMG recordings of the upper trapezius during work, and questionnaire data with information about neck pain and other health-related factors. Most of the data have been used in earlier publications (see Table 1). The final dataset consists of a total of 750 participants. All included datasets have both EMG and cross-sectional questionnaire data, and some have additional long-term prospective outcome data for 6 to 36 months (N = 260).

Objective Measures - EMG

The muscle activity of the upper trapezius muscle in the various datasets was collected bilaterally based on EMGs with a quality standard based on standard recommendations (Hermens et al., 1999). An overview of the specifications during EMG data collection is given in Table 2. The EMG data will be provided as quality-controlled files, meaning that each measurement will have been optically checked and cleared for artifacts by an instructed and trained person. Thereafter, the data were transformed from the original sampling frequency to the root–mean–square format (RMS) and normalized to MVE. The individual datasets will be pooled together with a common RMS frequency of 8 Hz and thereafter rechecked for quality. Datasets with a frequency different than 8 Hz will be interpolated accordingly to the target frequency of 8 Hz (spline interpolation).

Table 1. Overview on participating institutes and included professions.

References	Institute	Professions	n
Wærsted et al. (2019), Hanvold et al. (2016), Lunde et al. (2014)	National Institute of Occupational Health, Norway	Hairdresser, assistant worker, bricklayer, carpenter, cleaner, concrete worker, cook, kitchen helper, electrician, engineer, foreman, health care personal, office worker, project manager, student, working with various tasks	160
Mork and Westgaard (2004-2007)	Norwegian University of Science and Technology, Norway	Health care personal, retail personal, office worker	147
Brandt et al. (2018), Jakobsen et al. (2018)	National Research Centre for the Working Environment, Denmark	Project manager, bricklayer, concrete worker, assistant worker, student, retail personal, office workers, driver, meat cutter, mechanic, firefighter, brewery worker, gardener, forest worker, machine operator, warehouse worker, assembly worker, postal worker, other occupations	244
Østensvik et al. (2009, 2019)	Norwegian Institute of Bioeconomy Research	Harvester, forwarder, office worker	103
Dalager et al. (2020), Murray et al. (2016)	University of Southern Denmark	Surgeon, helicopter pilot	31
Balogh et al. (2019), Nordander et al. (2016)	Region Skåne, Sweden	Office worker, meat cutter, warehouse worker, assembly worker, windscreen inspection, rubber mixing, working with various tasks	44
Fan et al. (2022), Dahlqvist et al. (2017)	Karolinska Institute, Sweden	Surgeon, cleaner	21
		Total:	750

Table 2. Overview on specifications of EMG measurements of the various datasets.

References	Electrode placement	f	Procedure for MVE	Filters	f RMS
Hanvold et al. (2016)	2cm laterally to the midpoint between acromion C7	1024 Hz	Manual resistance against the arm abducted 90° in the scapular plane	High pass (10hz), 8th order Butterworth (400 Hz), Band- pass (300 Hz)	125 ms
Wærsted et al. (2019)	2cm laterally to the midpoint between acromion C7	1024 Hz	Arm abducted 90° in the scapular plane against resistance performed manually by the investigator	Band-pass (30–400 Hz), notch (50 Hz and all harmonics)	125 ms
Merkus et al. (2021), Lunde et al. (2014)	2cm laterally to the midpoint between acromion C7	1024 Hz	Shoulder abduction with arms elevated 90° in the scapular plane, against harness fixed at the elbows	Band-pass (30–440 Hz), notch (50 Hz and all harmonics)	125 ms
Mork and Westgaard (2004-2007)	2/3 of the distance from the spinous process of C7 towards the lateral edge of the acromion	1600 Hz	Both arms 90° abducted in the scapular plane and resistance applied just proximal to the elbow joint	Band-pass (20–800 Hz)	100 ms
Brandt et al. (2018), Jakobsen et al. (2018)	Over the upper trapezius muscles (Hermens et al., 1999)	1024 Hz	Standing position with 90° bilateral shoulder abduction and resistance applied above the wrist / Seated shoulder elevations against a rack, bilaterally placed on the medial part of the upper m. trapezius	High and Low pass (10 Hz / Hz Cutoff), 4th order Butterworth	500 ms / None
Østensvik et al. (2009)	2cm laterally to the midpoint between acromion C7	1280 Hz	Seated position with straight vertical arms pulling straps from proximal to the elbow and connected to a force transducer on the floor	Noise canceling	100 ms
Østensvik et al. (2009)	2cm laterally to the midpoint between acromion C7	800 Hz	Straight vertical arms with straps, located between handles and the force transducer	Band-pass (10-400 Hz), Band-pass (30-399 Hz)	100 ms
Dalager et al. (2020), Murray et al. (2016)	20% medial to half the length between the lateral part of the acromion and C7	1500 Hz	Shoulder elevation in upright standing position against a harness / Shoulder elevation in upright sitting position against force dynamometer	Low pass (500 Hz), High pass (10 Hz)	100 ms
Balogh et al. (2019), Nordander et al. (2016)	2cm laterally to the midpoint between acromion C7	1024 Hz	90deg arm elevation	Band-pass (30-400 Hz), notch filter (50 Hz)	125ms
Fan et al. (2022), Dahlqvist et al. (2017)	2cm laterally to the midpoint between C7 and acromion	1024 Hz	Elevation of shoulders statically against downward pressure on the upper arm	Digital bandpass filter (30-400 Hz)	125 ms

Variables of Interest

Widely used parameters of muscle activity in the literature are described. Based on the amplitude distribution of the EMG recordings, various levels of muscle activity can be described. Muscular rest is usually assumed to present at levels of muscle activity <0.5% MVE (Veiersted et al., 2013). By totaling the duration of all samples below 0.5% MVE and relating it to the total measurement duration, the relative rest time (RRT) can be calculated (Hansson et al., 2000). The number and duration of these rest pauses will also be calculated. The 10th percentile of the amplitude distribution is recommended as measure of a "static muscle activity level", while the 90th percentile describes the level of peak loads and median level (50th percentile) of the center of activity of the muscle during an EMG recording (Jonsson, 1982).

Gaps are short episodes of muscular rest. Their detection depends on the size length of the RMS conversion window and the level or threshold defining muscular rest or muscle activity. Previously, gaps in muscle activity were defined as time periods with EMG levels below 0.5% MVE (Veiersted et al., 1990). The minimum length of these gaps was 0.2 s due to their RMS frequency. A majority of gaps were found to last between 0.2 and 0.6 s during the examined working tasks. We will include different gap lengths in our analyses.

A description of long periods with continuous muscle activity will be given by calculating the number of SULMA periods. Depending on the duration, various ranges of the SULMA periods will be selected (Østensvik et al., 2009).

Subjective Measures

Questionnaire data for each participant were collected on the same day as the EMG measurements. All datasets contain general information about height, weight, and age of the participants. Other general information is available (\such as smoking status, working hours, dominant arm, and profession) depending on each dataset. The questionnaires were formulated in national languages or in English.

The questions concerning neck pain differed in type, formulation, answering categories, and requested time-period with neck pain in the individual studies. An overview of the various types of questions is given in Table 3. Based on the common intersection of all questions, it is conceivable that the outcome is presented as a dichotomized variable (pain/no pain). The questions on pain in the various studies cover different time periods ("Last three months", "last four weeks", "last seven days", "right now"). Some studies include more than one of these periods. Thus, sub-analyses will be performed with short-time measures (pain during measurement day) in addition to long-term measures of pain (last seven days to last four weeks). An analysis, including the entire dataset, will cover long-term pain measurements, assuming that short-term pain will be captured also in the long-lasting measures.

Table 3. Overview on various subjective measures on neck pain included in this study.

References	Questions	Answering category	Time frame
Wærsted et al. (2019)	Have you had neck complaints during the last 7 days?	Yes / No	Every 3 months (5x)
	Pain intensity in the neck and the upper back during the last 4 weeks	Not troubled Slightly troubled Somewhat troubled Severely troubled	
Lunde et al. (2014)	Pain intensity in the neck during the last 4 weeks		Every 6 months (6x)
Hanvold et al. (2016)	Pain intensity in the neck, shoulder, or upper part of the back during the last 4 weeks		Every 4 months (8x)
Mork and Westgaard (2004 - 2007)	Pain intensity the last 7 days	0 – 10 (VAS)	Baseline, 24 months
	Pain intensity the last 24 hours	0 – 10 (VAS)	
Brandt et al. (2018), Jakobsen et al. (2018)	Pain intensity in the neck or shoulder during the last 4 weeks	0 – 10 (VAS)	Baseline
Østensvik et al. (2019), Østensvik et al. (2009a)	Symptoms are present now or have been present most days in the last week?	Yes / No	Baseline
	Have you during the last 7 days non-specific symptoms present in the neck?	Yes / No	
Dalager et al. (2020)	Indicate the severity of your neck condition in the last 3 months: Please indicate the severity of your neck pain in the last 7 days:	0 – 10 (VAS) 0 – 10 (VAS)	Baseline
Murray et al. (2016)	Have you had any complaints in the neck during the last 7 days? Indicate the intensity of the pain in your neck right now.	Yes / No 0 – 10 (VAS)	Baseline
Balogh et al. (2019), Nordander et al. (2016)	Complaints (pain or discomfort) in the neck and right shoulder, elbow, and hand during the past seven days.	Yes / no	Baseline
Fan et al. (2022), Dahlqvist et al. (2017)	Have you had any neck complaints in the last 7 days?	Yes / no	Baseline
	Right now, are you experiencing any of these symptoms? (Neck Pain, Neck stiffness)	Yes / no	Baseline

Statistical Analyses

The data will be analyzed using IBM SPSS Statistics 25 (Armonk, New York, United States). The significance level will be set at $\alpha = 0.05$. The statistical analyses will be address the two hypotheses mentioned earlier.

To analyze the association of various EMG variables and neck pain linear mixed model regressions will be examined. Associations to neck pain will be examined separately and then combined. Analyses will be carried out unadjusted and adjusted for the following possible confounders: gender, job title/type, smoking status, age, body mass index (BMI), and profession.

To examine if the need for pauses differs depending on the physical or psychosocial demands of various occupations, the dataset will be clustered into job categories. The clustering will be done according to literature recommendations in addition to EMG parameters (number of peak loads, percentiles of muscular activity).

The job clusters will be used as confounders in the analyses. Comparison in descriptive parameters between job clusters will be done using an analysis of variance (ANOVA). The association of break parameters or parameters of low-level muscle activity will be investigated using multiple linear regression models. After unadjusted execution of the analysis, models adjusting for individual variables will be added.

Subgroups

The size of the final dataset will allow us to differentiate people according to gender, job categories, and others. With high numbers of participants in each subgroup, the precision of possible associations will be improved compared to smaller studies.

Sensitivity Analyses

Analyses will be examined with various threshold levels for gaps and periods of muscular rest in addition to specifications of SULMA periods. Additionally, we will check the sensitivity of results for minimal or maximal gap and pause lengths, and various definitions of SULMA duration. Variations of these indicators will affect the results as shown in other studies (Veiersted et al., 2013, Hansson et al., 2000).

DISCUSSION

This study is based on the belief that reduced muscle activity/increased rest may reduce the risk of developing neck pain. We were able to collect EMG data and questionnaire information from 750 participants in Scandinavia from various single studies. To our knowledge, only the study is comparable in its type and size (n = 646) as described by Balogh et al. (2019). Still, in that study, the authors included only the peak load activity of the trapezius muscle in their analyses.

Our pooled dataset may provide knowledge about how loads of the neck muscles, more specifically characterized by various percentiles related to MVE, peak loads, and sustained low-level muscle activity are associated with neck pain. On the other hand, the study may show how muscle recovery during work, specifically characterized by the presence of micro-pauses, periods with no/low muscle activity may influence the association of muscular load to neck pain. The results can be used to formulate recommendations for the use of breaks in various occupations to increase the level of safety, health, and well-being in working life.

Compared to previous studies, the number of included participants will give the opportunity to generate more scientifically valid results, examine and compare multiple occupational groups in one study, and also include multiple co-variates in the analyses. The included participants have a wide range of ages, heights and weights and will represent various professions in three different countries. The work tasks or jobs described in this study thus represent a broad spectrum of possible demands on an employee. It may therefore be possible to derive general results or recommendations that were previously only possible for specific occupational groups or work tasks.

Taking general individual factors into account, this study will examine whether single exposure features or a combination of them, contribute to an association between muscle activity and neck pain. Investigating the association of recovery parameters in the muscle activity pattern, this study might also find possibilities to reduce the risk of neck pain and help to clarify recommendations concerning the duration of necessary resting periods. These clear recommendations are missing in previous studies examining the association between pause lengths and neck pain.

Due to the objective measurement of the trapezius muscle activity, we will be able to provide a valid description of exposures as shown by the muscle activity pattern. Compared to previous studies with inaccurate subjective measurements, a clear advantage is present in this case. Transferring these results into practical application means that with the application of appropriate measurement methods, physicians, physiotherapists, and/or employees in occupational health management can measure the actual loads in the corresponding workplace and compare them with the reference values of this study. Methods for measurements of muscular activity have previously been expensive and technically complicated, but new electronic Bluetooth devices that are inexpensive and less complicated to use now exist. Subsequently, the work tasks can be adapted to reduce the risk of pain and the associated possible sick leave.

Methodological Considerations

The data size and composition of this study brings not only advantages but also certain disadvantages.

First, muscle activity measures from different institutes are compiled. These were collected, processed, and converted by different people and at different times. Some of the data is 20 years old and was collected with different measurement systems. As the end user of this data, we must trust in the high-quality acquisition and treatment of the measurement data in the various projects. All the included studies followed the recommendations of SENIAM (Hermens et al., 1999). Nevertheless, to establish certainty about the quality of the data, a visual and automated control was performed after pooling the data. The various filters in the measurement systems or the processing of the individual datasets before their conversation to RMS-format may have affected the data. Due to the enormous time required for a complete reprocessing of all data, these possible subtle differences must be accepted.

Second, most of the included studies are cross-sectional, which makes them susceptible to reverse causation, meaning that pain may influence the muscle activation pattern and not the opposite process. However, prospective outcome data may be provided from a considerable number of studies.

Third, the muscle activity pattern does not provide information on muscle length or the biomechanical work of the muscle. This lack of information may be important in the case of the trapezius since in the case of certain arm positions, in combination with high muscle tension, nerve bruising may occur. In some of the included studies, information about the upper arm angle can be provided. The additional consideration of this information in the analyses, including the necessary data preparation, would exceed the time frame of this study. However, our information offers the possibility to deepen or expand the current study at a later stage.

Fourth, a major drawback of this study is that the subjective assessment of neck pain was recorded using questionnaires with different types of questions. Differences can be found in the studied period (punctual, acute, chronic) and answer categories, but also in the pain localization (shoulder, neck, both). This represents a major imprecision for the outcome of the analyses. The significance of the results regarding neck pain can therefore only be based on its presence over the last four weeks. An inaccuracy in the two studies in which shoulder and upper back pain are recorded concurrently also is present. To reduce/check this inaccuracy, the analyses will be carried out without these datasets.

Concluding Remarks

This study consisted of a pooled dataset and will provide further insight into the possible association between sustained upper trapezius muscle activity and neck pain. This knowledge aims to inform on recommendations for preventing work-related neck pain.

Ethics Approval and Consent to Participate

The consent for the pooling, storing and analysis of the various anonymized datasets was given by the Norwegia,n Centre for Research Data (Application number: 275929; REK sør-øst B, Gullhaugveien 1-3, 0484 Oslo).

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