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Cross-sectional Study of Upper Trapezius Muscle Activity and Self-Reported Neck/Shoulder Pain

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The purpose of this cross-sectional study was to compare the observed associations between upper trapezius muscle activity, as estimated with several summary measures obtained from surface electromyography (EMG), and self-reported neck/shoulder pain among a sample of 231 manufacturing workers. EMG methods used in this study included mean root-mean-square amplitude, the amplitude probability distribution function (APDF), EMG gaps analysis, and clustered exposure variation analysis. The observed seven-day prevalence of neck/shoulder pain was 13.9%. Of the EMG summary measures, only the 90th percentile of the APDF was significantly associated with symptoms, with crude and adjusted odds ratios of 2.57 (1.02-6.49) and 2.78 (1.07-7.21) per natural log unit, respectively. This study was largely inconclusive due to the similarity in the distributions of the summary measures between symptomatic and non-symptomatic participants, and explicit measures of posture and repetition may produce stronger associations with symptoms.

INTRODUCTION

Surface electromyography (EMG) is a direct method of assessing exposure to forceful exertion, and may produce more precise exposure estimates than common self-report or observational methods (Winkel & Mathiassen, 1994; Burdorf & van der Beek, 1999). However, the cost associated with collecting EMG data in large epidemiologic studies has limited its use mainly to small studies with small numbers of participants.

The advent of portable instrumentation systems has increased the viability of EMG data collection in field studies (Asterland, Hansson, & Kellerman, 1996; Sandsjö, 1997). Also, data reduction schemes have been reported that provide information along two more exposure dimensions (intensity, frequency, and duration) (Jonsson, 1982; Veiersted, Westgaard, & Andersen, 1990; Mathiassen & Winkel, 1991; Anton, Cook, Rosecrance, & Merlino, 2003). However, information about the associations between different EMG summary measures and adverse health outcomes within the context of the same analysis is lacking.

The multitude of EMG analysis methods used in occupational ergonomics studies, and the different aspects of forceful exertion exposure each describes, can lead to uncertainty when choosing appropriate EMG exposure variables in epidemiologic studies. Therefore, the objective of this study was to compare the associations between several EMG summary measures and self-reported neck/shoulder pain.

METHODS

Study Population

The study sample consisted individuals enrolled in a prospective cohort study to examine the associations between physical risk factors and the prevalence and incidence if upper extremity musculoskeletal disorders (UEMSD) among household appliance manufacturing workers at a single facility. All males and females over 18 years of age and employed in production jobs were eligible to participate. Enrollment of participants into the prospective study began on April 14, 2004. Presented

here is a cross-sectional analysis of all study participants enrolled as of December 12, 2005.

Health Outcome Assessment

The presence of neck/shoulder symptoms was assessed with a personal health questionnaire administered at entry. Participants were classified as prevalent for neck/shoulder symptoms if they 1) reported an occurrence of pain, numbness, or tingling in the neck/shoulder region lasting at least 30 minutes during the previous seven days on the dominant side, and 2) reported a symptom severity of five or greater on a 10 cm visual analog scale (VAS), or used medication to alleviate the discomfort regardless of symptom severity.

Exposure Assessment

An individual, task-based strategy was used to estimate exposure to forceful exertions. All EMG recordings were unilateral on the dominant side and the electrode was positioned on the skin over the upper trapezius according to standard placement guidelines (Zipp, 1982).

The EMG electrodes (EQ, Inc., Chalfont, PA) consisted of two 8 mm silver-silver chloride disks encased in 33x10 mm plastic housings, an interelectrode distance of 22 mm, and onsite preamplification with a gain of 35. A reference electrode was positioned over the clavicle on the non-dominant side. The electrodes were attached to a data logger consisting of a microprocessor and 12-bit analog-to-digital converter (Tattletale_v2, Onset Computer Corp., Pocasset, MA), a custom EMG instrumentation board, and a compact-flash data storage board (PERCF2V2I, Persistor Instruments, Inc., Bourne, MA). On the instrumentation board, the preamplified EMG signals were further amplified with a gain of 2000, bandpass filtered between 10 and 4000 Hz, and real-time processed to root-mean-square (RMS) amplitude with a 100 ms time constant. The RMS-processed signals were sampled at 100 Hz and stored on compact flash memory. EMG signal quality was monitored with a separate 12-bit analog-to-digital PCMCIA card (PCM-16/330, Datapac MS-2, RUN Technologies, Mission Viejo, CA) and a laptop personal computer running LabVIEW® data acquisition and signal processing software (National Instruments, Austin, TX).

Normalization of the EMG data was accomplished with standard sub-maximal reference voluntary exertions (RVE) (Mathiassen, Winkel, & Hägg, 1995). Muscle activity was then sampled for a minimum of 10 minutes for each task that a participant normally performed during the course of a work week. Measurements were obtained within two weeks of enrollment, and all task EMG data were analyzed with custom software (Fethke, Anton, Fuller, & Cook, 2004). EMG summary measures computed for each task included: mean RMS amplitude, amplitude probability distribution function (APDF) (Jonsson, 1982), clustered exposure variation analysis (CEVA) (Anton et al., 2003), and EMG gaps analysis (Veiersted et al., 1990) (Table 1). Time-weight-averaged (TWA) exposure for the week following enrollment was then calculated for each summary measure using information from both the EMG data record and a task log from the first week of prospective observation.

Statistical Analyses

The association between forceful exertions and self-reported neck/shoulder symptoms was assessed using logistic regression. Separate univariate analyses were performed for each EMG summary measure, formulating prevalence odds ratios and confidence intervals. Odds ratios from the univariate models for which the p-value was 0.20 or less were then adjusted for age, gender, body mass index, smoking status, years of employment at the study facility, and current job stress. All statistical analyses were performed in SPSS version 12.0.1 (SPSS Inc., Chicago, IL).

RESULTS

Between April 14, 2004 and December 5, 2005, 404 eligible production employees were invited to participate in the prospective study. Of those, 263 (65.1%) gave written informed consent and completed the personal health questionnaire. One enrolled participant moved to an ineligible job prior to collection of the EMG data, 25 did not complete the task log for the first week of observation, and instrumentation failures resulted in the loss of data for 6 participants. Thus, complete exposure and health outcome data were available for 231 participants. Characteristics of the study sample are included in Table 2.

Of the 231 participants, 32 (13.9 %) met the case definition (VAS score ≥ 5 or taking medication for pain). Means and standard deviations of the EMG summary measures for symptomatic and non-symptomatic participants are provided in Table 3. The most notable difference between non-symptomatic and symptomatic participants was observed for the 90th percentile APDF, with a higher level of TWA exposure for the symptomatic

group (140.32 %RVE vs. 120.45 %RVE). On average, less than 0.2% of work time was spent in the high amplitude CEVA categories (> 400% RVE), indicating that high intensity upper trapezius contractions were not contributing greatly to the exposure of either the non-symptomatic or symptomatic participants. Therefore, associations between the high amplitude CEVA categories and neck/shoulder symptoms were not assessed with logistic regression models.

The distributions of TWA values for each summary measure were positively skewed (not shown). Therefore, natural log transformation was performed prior to statistical analysis. Results of the univariate logistic regression analyses are displayed in Table 4. For the EMG measures, the unadjusted odds ratios and corresponding confidence intervals are provided in terms of natural log-transformed units. None of the personal or occupational variables were univariately associated with neck/shoulder symptoms. Of the EMG summary measures, only the 90th percentile APDF exhibited a significant association with neck/shoulder symptoms (OR_{crude} = 2.57 per log unit; 95% CI = 1.02-6.49; p = 0.04). After adjustment for gender, age, BMI, smoking status, years at the study facility, and current job stress, only a small increase in the odds ratio was noted (OR_{adj} = 2.78 per log unit; 95% CI = 1.07-7.21; p = 0.04), suggesting the unadjusted odds ratio was not meaningfully confounded by personal and occupational factors.

DISCUSSION

The observed prevalence rate for neck/shoulder symptoms (13.9%) is somewhat lower than rates reported among other populations of manufacturing workers. Punnett (1998) observed a 12-month prevalence rate of 22% for neck/shoulder symptoms among 1198 automobile production employees across two facilities. Similarly, Latko et al. (1999) reported a 12-month prevalence rate of 37% for non-specific distal UE discomfort among 352 workers from three manufacturing sites. If the case definition in this study included participants reporting neck/shoulder symptoms of any severity, the seven-day prevalence rates would be 37% (86/231), which compares favorably to previous studies.

In general, little difference in the distributions of the EMG summary measures was observed between the symptomatic and non-symptomatic participants. Consequently, except for the 90th percentile APDF, the results of the logistic regression analyses failed to identify statistically significant associations between EMG summary measures and self-reported neck/shoulder symptoms.

Overall, the 231 study participants performed 581 tasks, an average of 2.5 tasks per participant. For each participant, the EMG summary measures were time-weight-averaged according to the proportion of the total working hours spent at each task, thereby arriving at an aggregate exposure estimate. While TWA exposure estimation has been advocated for EMG measures (Winkel & Mathiassen, 1994), this is the first epidemiologic study to present time-weight-averaged EMG results for all participants.

Clearly, the TWA values depend on the time distribution of task hours reported on the weekly task log. The cross-sectional design assumes measured exposures to reflect the exposure profile leading to the onset of reported symptoms. During the prospective observation of the participants included in this study, substantial variation in the weekly distribution of job tasks has been noted. Although obtaining exposure measurements within two weeks of entry minimized the chance of collecting EMG information for tasks unrelated to the onset of symptoms, the time distribution of tasks prior to measurement could have been quite different than as reported on the first weekly task log.
Additionally, during prospective observation, 35 of the 231 (15%) study participants have moved from their originally measured job into a job with completely different tasks. Eleven study participants (5%) have changed jobs at least twice since enrollment. Therefore, measurement error in this study is primarily a combination of 1) random error in the measured TWA exposures for all participants due to weekly variations in task time allocation and 2) error due to measurement of exposures that may not be related to the presence or absence of symptoms. As a result, the observed odds ratios in this study are expected to be null-biased.

Potential misclassification of symptom status was minimized two ways. First, as participants were asked to report symptom experience during the seven days prior to enrollment, the recall period was quite short. Second, the symptom severity sufficient for a participant to be classified as symptomatic was a score of five or greater on the VAS, which is more restrictive than previous cross-sectional studies of physical risk factors and UEMSDs among manufacturing workers (Fransson-Hall, Byström, & Kilbom, 1995; Punnett, 1998; Latko et al., 1999). While even a minor episode of pain resulting from working activities could be considered an adverse event requiring intervention, a less restrictive case definition may have overestimated the observed prevalence rate and

increased the chance of classifying participants suffering from transient low-level discomfort as symptomatic. Clinical examination of symptomatic participants, while performed as part of the prospective study, was not conducted in this study.

Although forceful exertion was of primary interest in this study, high repetition rates and awkward postures were observed in many tasks. Relevant measures of repetition and posture may indicate stronger associations with symptoms than forceful exertion. Although repetition was not explicitly assessed in this study, the EMG gap frequency and short duration CEVA summary measures reflect the repetitiveness of muscle contractions. Only minimal differences in these measures were observed between symptomatic and non-symptomatic participants.

CONCLUSION

This cross-sectional study did not identify strong associations between most EMG summary measures commonly used for assessment of exposure to forceful exertion and self-reported neck/shoulder symptoms. This observation was not likely the result of low symptom prevalence since the observed symptom prevalence rates were comparable to those found in other cross-sectional studies of manufacturing workers. However, there was minimal contrast in exposure to forceful exertion between symptomatic and non-symptomatic participants as estimated with surface EMG in this study. Although the 90th percentile of the APDF for upper trapezius EMG activity was statistically significantly associated with neck/shoulder complaints, no other EMG measures were statistically significantly associated with self-reported symptoms.

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TABLES

Table1: EMG data reduction schemes and summary measures. Amp = amplitude, Dur = duration.

Data Reduction Scheme	Summary Measures (Units)
Basic	Mean RMS Amplitude (%RVE)
Amplitude Probability Distribution Function (APDF)	10% probability level (%RVE) 50% probability level (%RVE) 90% probability level (%RVE)
Clustered Exposure Variation Analysis (CEVA)	Low Amp – Short Dur (%Time) Low Amp – Prolonged Dur (%Time) Moderate Amp – Short Dur (%Time) Moderate Amp – Prolonged Dur (%Time) High Amp – Short Dur (%Time) High Amp – Prolonged Dur (%Time)
Gap Analysis	Gap Frequency (# of gaps per minute) Rest Time (%Time)

Table 2: Characteristics of the study sample.

Characteristic	Frequency or Mean (SD)	Percent
Gender		
Male	101	43.7
Female	130	56.3
Age (years)	44.0 (9.4)	
Height (m)	1.71 (0.1)	
Weight (kg)	80.7 (18.1)	
Body Mass Index (kg/m^2)	27.6 (5.6)	
Smoking Status		
Smoker	74	32.0
Non-smoker	157	68.0
Years Employed at Facility	18.0 (10.6)	
Current Level of Job Stress	3.1 (2.1)	

Table 3: Mean (SD) of the upper trapezius EMG summary measures, by symptom status.

EMG Summary Measure	Non Symptomatic	Symptomatic
Mean RMS Amplitude	45.5 (18.3)	48.7 (17.5)
APDF		
90th Percentile	120.5 (55.6)	140.3 (66.2)
50th Percentile	34.3 (17.0)	34.5 (14.0)
10th Percentile	4.6 (4.2)	4.1 (2.2)
Gap Analysis		
Gap Frequency	14.4 (7.8)	14.5 (6.9)
Percent Rest	13.2 (8.6)	13.4 (8.0)
CEVA		
Low Amp – Short Dur	26.8 (12.0)	26.8 (7.8)
Low Amp – Prolonged Dur	9.5 (9.1)	10.1 (8.6)
Moderate Amp – Short Dur	28.5 (13.1)	29.4 (10.3)
Moderate Amp – Prolonged Dur	4.1 (4.5)	3.7 (4.3)
High Amp – Short Dur	0.1 (0.4)	0.2 (0.8)
High Amp – Prolonged Dur	0.0 (0.0)	0.0 (0.0)

Table 4: Unadjusted odds ratios and 95% confidence intervals for prevalent neck/shoulder symptoms in relation to EMG summary measures and personal and occupational variables.

Factor		*OR_{crude}*	*95% CI*	*p-value*
Gender	Female	ref		
	Male	0.74	0.44 – 1.60	0.45
Age		0.99	0.96 – 1.03	0.79
BMI		0.99	0.93 – 1.06	0.84
Smoking	Non-Smoker	ref		
	Smoker	1.04	0.47 – 2.33	0.92
Years at Study Facility		0.99	0.96 – 1.03	0.93
Current Job Stress		1.00	0.84 – 1.21	0.94
ln(Mean RMS Amplitude)		1.71	0.66 – 4.41	0.27
ln(90% APDF)		2.57	1.02 – 6.49	0.04
ln(50% APDF)		1.20	0.59 – 2.44	0.61
ln(10% APDF)		1.05	0.61 – 1.80	0.85
ln(Gaps Per Minute)		1.19	0.61 – 2.31	0.61
ln(Rest Time)		1.10	0.62 – 1.93	0.75
ln(Low Amp – Short Dur)		1.35	0.59 – 3.13	0.48
ln(Low Amp – Prolonged Dur)		1.17	0.77 – 1.78	0.46
ln(Moderate Amp – Short Dur)		1.43	0.65 – 3.13	0.37
ln(Moderate Amp – Prolonged Dur)		0.97	0.61 – 1.55	0.99