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Level of self-reported neck/shoulder pain and biomechanical workload in cleaners

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Abstract. The aim of the present study was to investigate the relation between self-reported pain, muscular activity and postural load during cleaning tasks. Eighteen cleaners performed usual cleaning tasks in both a laboratory and a lecture room. The level of perceived pain in the neck-shoulder region during the last 7 days was recorded. Bipolar surface electromyography (SEMG) was recorded bilaterally from upper trapezius and erector spinae muscles during cleaning. Root mean square (RMS) and permutation entropy (PE) values representing amplitude and complexity of SEMG time-series were estimated. A tri-axial accelerometer package was mounted on the low back (L5-S1) to measure postural changes during cleaning tasks. The 10^{th}, 50^{th} and 90^{th} percentiles of the angular distributions were computed to characterize postures and movements. Pain tended to play a significant role on RMS of left/right trapezius and left erector spinae muscles ($P \leq 0.08$). Cleaners with low pain level exhibited higher muscular activity during cleaning. Pain played or tended to play a significant role on PE of left and right erector spinae muscles ($P \leq 0.08$). Pain played a significant role on the 10^{th}, 50^{th} and 90^{th} percentile ($P<0.05$) of lateral flexion angle (side bending). The present study emphasizes biomechanical adaptations occurring in presence of neck-shoulder pain during cleaning tasks.

Keywords: complexity, electromyography, inclinometry, motor adaptations

1. Introduction

Occupations like cleaning involving repetitive arm movements, awkward postures and insufficient rest are associated with at high risk of developing work-related musculoskeletal disorders (WMSD) affecting back, neck, shoulder, elbow and hands [12,16]. WMSD are often resulting in frequent absenteeism, long-term sick leave with tremendous socio-economical effects.

WMSD are often accompanied by pain located in deep structures. Efforts have been done in order to obtain more information of the influence of muscle pain on the motor system [4]. However these efforts are mostly limited to laboratory studies and there is a lack of studies measuring physical exposure in a reliable manner in situ. Further, the existing literature has until recently omitted to study motor control aspects in details by assessing motor variability [4].

More specifically, nonlinear approaches can be used to study the structure of variability. Entropy measures are probably the most common index of complexity in surface electromyographic (SEMG) or kinematic time-series. Such methods are likely to delineate the effects of pain on the motor system as changes have been reported in relation to discomfort and diseases [7,11]. Thus, assessing the biomechanical loads during cleaning tasks in relation to pain can furnish important information about the underlying motor adaptation processes.

The aim of the present study was to investigate the effects of self-reported pain on muscular activity and postural load during cleaning tasks.

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2. Methods

2.1. Subjects

Eighteen University cleaners (3 males and 15 females) participated in the study (mean age 48 (SD 9) years, height 166 (SD 7) cm and body mass 71 (SD 14) kg). All, except one were dominant right handed. The study was conducted in conformity with the declaration of Helsinki, and experimental procedures were approved by the local ethics committee (N-20070004). All subjects signed an informed consent after being explained the study protocol both verbally and in written text.

2.2. Protocol

All cleaners performed the cleaning tasks in two locations: i) cleaning in a laboratory of 12 m^2 for 3 min and ii) a lecture room of 30 m^2 for 7 min. The cleaners were asked to work at their usual pace. The tasks performed in the two rooms differed: For example, lecture room required to clean wide blackboards, rows of desks while the laboratory necessitated dust removal from equipment using a duster.

All cleaners started by cleaning first the laboratory and continued with the lecture room. The cleaning tasks were performed in two sessions, one following ergonomics guidelines (ergonomics session) and one performed as the cleaner would normally do the work (non-ergonomics session). The order of ergonomics and non-ergonomics session was randomized but to minimize any possible carry over effect, special care was taken to keep a balanced data set.

The cleaning tasks consisted of mopping the floor, sweeping and loading it off to the garbage bin and changing its plastic bag, cleaning the rows of desk, backboards. In ergonomics sessions, the cleaners were instructed to avoid extreme shoulder movement while they mop the floor and keep the mop rod along with body forward movement, squat instead of stoop bending wherever bending was required. The instructions were similar to the instructions that they regularly during daily work received at briefing session. In non-ergonomics session, stoop bending and extreme movement of the shoulder were allowed. An observer was following the cleaners during whole recordings and ensured that the cleaning tasks were done according to the instructions.

Once the subjects had received instructions and SEMG electrodes and accelerometer were mounted (see part 2.3.), the recordings were sequentially performed as explained below. The cleaners were asked to perform:

1) Reference contractions: For the shoulder muscles, it consisted of abilateral shoulder abduction while seating upright for 5 s used for normalization of SEMG. For the low back muscles, it consisted of 20º forward flexed upper body while standing with arms vertical.
2) Cleaning tasks. The performed motor tasks were usual ones, i.e. mopping, sweeping, changing the trash bins and cleaning the desks and blackboards in the laboratory and/or the lecture room.

2.3. Data acquisition and processing

Level of perceived pain (average of the score for the neck and the shoulders region during 7 days before the day of the experiment) was scored by the cleaners on a scale anchored with zero as “no pain” and 10 as “Worst pain ever”. The pain intensity was categorized as low (<3), moderate (>3 and <7) and high (> 7).

SEMG was collected from the descending (bilateral) of the trapezius muscles and erector spinae (ES). Bipolar surface electrodes (Ambu A/S, Neuroline, Ballerup, Denmark) were aligned (inter-electrodes distance 2 cm) on abraded ethanol-cleaned skin along the direction of the muscle fibres. Electrodes were placed ~20% lateral to the midpoint between the acromion and the C7 vertebra for the descending (ipsi- and contra-lateral side) part of trapezius and 3 cm lateral to the posterior spinous process at the level of L3 for ES. The reference electrode was placed on the C7 vertebra. The SEMG signals were amplified 1000 times, and band-pass filtered (10-500 Hz). EMG signals were sampled at 1 kHz using a portable data-logger (weight 900 g, size 6×10×19 cm) fastened around cleaner waist by a belt.

Reference voluntary electrical (RVE) activity was calculated as the mean of SEMG root mean square (RMS) during reference contraction calculated over 250 ms epochs moving in steps of 100 ms for each muscle. For the cleaning tasks, RMS and permutation entropy (PE) values were estimated for 0.5 s non overlapping epochs of EMG time-series. Five rectangular windows were applied on RMS and PE sequences representing 0-100% interspaced with 25%.

Inclinometer, based on a triaxial accelerometer, was used to measure the angle relative to the line of gravity for the lower back. Data were sampled at 100

Hz using the same data-logger explained in previous paragraph. Reference contractions explained in section 2.2. were used to transform from the inclinometer to the body segment using the method introduced in [3]. The accelerometer package was 55×25×30 mm and weighted 40 g which cantered at the level of L5/S1. The package was stuck to the body using double-layer adhesive tape and fixed with tapes around it.

The forward/backward and sideways projections of the inclination angles (flexion/extension and lateral flexion below) and the absolute value of their time derivatives were used to describe postures and movements [2].

The 10^{th}, 50^{th} and 90^{th} percentiles of the angular and the angular velocity distributions were used to characterize postures and movements.

Table 1

Mean and SD values of the root mean square (RMS, mV), normalized root mean square (NRMS, %) and permutation entropy (PE) of the left and right erector spinae and trapezius muscles and of the 10^{th}, 50^{th} and 90^{th} of the lateral flexion angle and angular velocity in relation to self-reported pain (low, moderate and high pain level) during cleaning tasks in a laboratory with sessions following or not following ergonomic guidelines

Session	Following ergonomic guidelines						Not following ergonomic guidelines					
Pain	Low		Moderate		High		Low		Moderate		High	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SEMG												
Left erector spinae												
RMS	26,2	14,1	23,9	8,8	11,1	1,1	29,4	15,7	23,9	13,3	14,5	2,4
NRMS	104,2	16,6	126,9	20,0	123,2	14,4	117,9	20,2	117,3	17,3	169,0	34,9
PE	0,895	0,008	0,899	0,008	0,898	0,012	0,888	0,009	0,902	0,003	0,898	0,006
Right Erector spinae												
RMS	26,0	15,2	18,3	3,4	17,4	3,4	28,2	15,3	17,7	6,6	18,2	4,7
NRMS	108,5	21,4	127,4	10,1	129,1	22,5	122,4	23,3	120,9	32,7	121,8	14,0
PE	0,897	0,010	0,900	0,009	0,897	0,007	0,891	0,012	0,900	0,002	0,898	0,007
Left trapezius												
RMS	35,4	16,6	47,1	17,9	21,4	4,5	43,5	18,2	52,4	30,6	30,5	11,2
NRMS	14,5	1,9	23,7	14,3	13,3	2,2	20,9	4,6	24,1	5,1	24,3	7,0
PE	0,861	0,015	0,829	0,023	0,874	0,014	0,868	0,012	0,835	0,022	0,866	0,014
Right trapezius												
RMS	57,3	27,7	34,4	8,7	23,7	6,5	72,7	32,0	60,9	29,9	38,9	11,4
NRMS	19,3	4,2	19,4	13,2	14,2	2,5	27,2	5,4	27,0	7,8	22,8	6,0
PE	0,864	0,018	0,860	0,005	0,873	0,009	0,865	0,015	0,860	0,009	0,866	0,013
Lateral Flexion												
Angle (°)												
10^{th}	-7,5	0,9	-8,8	3,7	-14,2	4,7	-8,3	1,1	-9,5	1,25	-13,2	2,0
50^{th}	1,2	0,9	-0,14	1,8	-6,6	4,9	1,4	1,3	0,0	2,0	-1,5	2,0
90^{th}	9,7	1,8	9,2	0,15	1,4	5,3	11,4	1,6	10,3	1,8	8,9	2,7
Angular velocity (°/s)												
10^{th}	2,8	0,4	2,5	0,1	2,5	0,4	3,6	0,3	2,8	0,4	3,3	0,35
50^{th}	19,8	3,3	18,3	2,2	16,0	2,6	24,2	2,4	20,9	2,9	22,7	2,5
90^{th}	72,6	9,05	71,2	4,8	61,4	7,8	85,5	7,5	80,1	9,6	84,5	7,5

2.4. Statistical analysis

Ergonomics guidelines and time were introduced as within-subject factors and level of perceived pain as a covariate in a full-factorial repeated measure analysis of covariance for, absolute and normalized RMS and PE as EMG dependent variables, 10^{th}, 50^{th} and 90^{th} percentile of forward and lateral flexion/ extension and corresponding angular velocity as inclinometer dependent variables. The within subject independent factors were Ergonomics guidelines (Ergo-Non Ergo) and time (0-25-50-75-100%). If the assumption of sphericity was not met, a correction was applied (Greenhouse Geisser with epsilon value below 0.75). In all tests, $p<0.05$ was considered significant. If a factor with more than two levels was defined as significant, the corrected Bonferroni post hoc test was applied.

3. Results

3.1. Cleaning tasks in a laboratory

Pain tended to play a significant role on PE of left ES (P=0.05) and the interaction of guidelines × pain tended to play a significant role on PE of left trapezius (P=0.08) and right ES (P=0.08). Cleaners with higher pain level showed higher PE following ergonomic guidelines (Table 1).

Pain played a significant role on 10^{th}, 50^{th} and 90^{th} percentile (respectively, P=0.01, 0.02 and 0.04) of lateral flexion angle (side bending). Interaction of neck pain × guidelines tended to play a significant role on 50^{th} and 90^{th} percentile (P=0.06 and 0.08 respectively) of lateral flexion angle (side bending). The cleaners with higher pain were leaning to their right side (Table 1).

Table 2

Mean and SD values of the root mean square (RMS, mV), normalized root mean square (NRMS, %) and permutation entropy (PE) of the left and right erector spinae and trapezius muscles and of the lateral flexion angle and angular velocity in relation to self-reported pain (low, moderate and high pain level) during cleaning tasks in a lecture room with sessions following or not following ergonomic guidelines

Session	Following ergonomic guidelines						Not following ergonomic guidelines					
Pain	Low		Moderate		High		Low		Moderate		High	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SEMG												
Left erector spinae												
RMS	22.6	9.5	16.5	1,2	11,4	2,4	25,3	9,8	15,0	1,6	14,3	2,3
NRMS	102,0	21,9	132,5	21,6	148,0	29,1	118,1	26,2	116,7	12,1	172,3	30,1
PE	0,897	0,008	0,895	0,002	0,908	0,004	0,887	0,008	0,897	0,003	0,891	0,014
Right erector spinae												
RMS	24.6	11,7	14,2	1,0	18,6	6,9	25,5	10,3	14,7	1,3	17,2	4,2
NRMS	118,8	30,3	115,4	11,3	126,6	18,8	133,7	35,8	119,3	11,4	126,5	11,9
PE	0,894	0,009	0,895	0,002	0,903	0,008	0,886	0,010	0,897	0,003	0,891	0,016
Left trapezius												
RMS	36,0	16,6	50,6	10,7	23,8	4,8	40,3	21,5	56,9	17,2	35,8	7,5
NRMS	14,4	2,1	28,8	4,6	14,2	1,3	18,4	2,2	30,5	3,2	20,9	2,0
PE	0,873	0,015	0,831	0,020	0,881	0,009	0,872	0,014	0,833	0,017	0,871	0,009
Right trapezius												
RMS	55,4	20,8	32,0	2,9	26,8	7,5	70,9	28,0	40,4	7,6	43,0	13,7
NRMS	20,9	4,9	20,9	5,3	16,1	2,4	26,6	3,3	24,1	4,7	25,1	6,1
PE	0,859	0,019	0,861	0,005	0,872	0,011	0,858	0,009	0,856	0,005	0,863	0,013
Lateral Flexion												
Angle (°)												
10^{th}	-6,6	1,1	-10,6	1,3	-14,9	6,8	-7,9	1,6	-10,3	0,5	-13,7	1,6
50^{th}	1,7	1,3	-0,9	0,6	-7,0	6,8	3,2	1,5	-0,35	1,25	-3,2	1,2
90^{th}	9,6	2,3	8,2	0,3	2,2	6,7	14,0	1,9	10,2	0,4	7,09	1,3
Angular velocity (°/s)												
10^{th}	3,8	0,6	3,5	0,5	3,2	0,3	4,6	0,4	3,8	1,2	3,9	0,1
50^{th}	25,7	3,8	22,2	2,3	21,5	2,0	29,5	2,4	24,6	4,5	26,6	2,4
90^{th}	88,9	9,7	76,7	3,5	84,4	7,0	104	9,5	88,8	12,0	98,1	3,9

3.2. Cleaning tasks in a lecture room

Pain tended to play a significant role on RMS of right trapezius and left ES (P=0.08 and P=0.08). Cleaners with lower pain level showed higher muscular activity (Table 1). Pain played a significant role on normalized RMS of left trapezius (P=0.04) and interaction of Guidelines × pain also played a significant role on normalized RMS of right ES (P=0.04).

Pain tended to play a significant role on PE of left ES (P=0.07) and the interaction of guidelines × pain played a significant role on PE of right ES (P=0.02) and the interaction of time × pain tended to play a significant role on PE of left ES (P=0.06). Cleaners with higher pain level showed higher PE following ergonomic guidelines (Table 2).

Pain played or tended to play a significant role on 10^{th}, 50^{th} and 90^{th} percentile (respectively, P=0.04, 0.02 and 0.06) of lateral flexion angle (side bending). The cleaners with higher pain were also leaning to their right side (Table 2).

Pain also played a significant role on 10^{th} percentile (P=0.04) lateral flexion (side bending) angular velocity (Table 2). Interaction of pain × guidelines played or tended to a significant role on 10^{th}, 50^{th} and 90^{th} percentile (P=0.03, 0.05 and 0.08 respectively) of flexion angle (forward bending). However, following ergonomic guidelines did not contribute significantly to a decrease in the range of motion and angular velocity for the cleaners at higher level of pain.

4. Discussion

The cleaners with lower levels of perceived pain in neck and shoulder region within the last week tended to show higher activity in the right trapezius and left erector spinae and those with higher pain level showed higher complexity following ergonomic guidelines. The higher the pain, the more the cleaners were leaning to their right side (all but one were right handed). Among the cleaners with low self-reported pain level, the range of trunk lateral flexion and its angular velocity decreased significantly when performing cleaning tasks following ergonomic guidelines. Increased pain level lessened the effect of Ergonomics guidelines.

4.1. Methodological considerations

The time allowed for performing the cleaning tasks in the laboratory and the lecture room was based on daily working conditions with normal pace. All cleaners could perform the cleaning tasks resulting in similar productivity in both the ergonomics and non-ergonomics sessions.

In this study, we only recorded SEMG from four muscles preventing us from extracting global muscles activation strategies. RMS values were computed and then normalized to a reference contraction to account for inter-individual factors [10]. However, SEMG normalization is also inducing some variability that may mask differences among e.g. low-back patients and controls [14]. We also computed the permutation entropy due to its lower computational cost [1]. Entropies measures quantify the occurrences of recurrent patterns in the studied time series providing information of the structural variability of exposure. This type of parameter provides information not revealed by conventional parameter like amplitude parameters[7]. Interestingly, entropy measures have shown to be particularly effective in cross-sectional design investigating e.g. healthy subjects and patients [9]. However, further studies with larger population size are warranted.

4.2. Self-reported pain and biomechanical load

In terms of SEMG amplitude, both a lack of changes in SEMG amplitude of shoulder muscles e.g. trapezius and deltoid [5;13] and more frequently an increase have been reported with comparing controls to patients with neck-shoulder pain [6;15]. Similar controversial results exist in low-back pain patients [14]. Thus, the observed trends towards increased SEMG activity in both trapezius and in the left erector spinae muscles among cleaners with self-reported neck-shoulder pain are mostly in line with the literature. Such increases underline an inability to relax among cleaners with neck-shoulder pain supporting hyperactivity theories. Further, higher levels of muscle activity may lead to the spreading of pain to remote areas such as the low-back region.

The cleaners with high pain level showed higher entropy when following ergonomic guidelines in the erector spinae muscles while there was no such effect if they did not follow the ergonomics guidelines. The differences in permutation entropy values in relation to self-reported pain are in agreement with a recent study showing higher structural complexity among patients diagnosed with medial tibial stress syndrome [11]. The present results confirm that assessing structural variability is a way to characterize the effects of pain in the motor system in ergonomics situations.

The trunk kinematics were also affected by self-reported pain. This is also in line with a number of studies investigating repetitive work in presence of acute, sub-chronic and chronic neck-shoulder pain [5;6;8]. The cleaners with higher pain level were leaning more to their right side. As most of them (all except one) were right handed, it seems they adopted a different motor strategy when performing cleaning tasks by adopting a posture enabling to cope with neck-shoulder pain [4]. Moreover, in terms of forward flexion, the cleaners with low pain level avoided extreme trunk bending and fast movement when following the ergonomic guidelines. This can be considered as positive trait. This potentially beneficial effect became less potent among the cleaners with higher self-reported pain level. The present study emphasizes biomechanical adaptations occurring in presence of self-reported neck-shoulder pain during cleaning tasks.

5. Conclusion

The present study investigated biomechanical exposure in relation to self-reported neck-shoulder pain among cleaners. The reported changes in terms of SEMG amplitude and complexity values as well as in angular displacement and velocity in presence of neck-shoulder pain confirmed the important role of assessments conducted in real work environment. Further, such methods provide important quantitative measures that contribute to assess the effect of ergonomics interventions aiming at reducing the occurrence of WMSD.

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