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Original Article

Effects of mop handle height on shoulder muscle activity and perceived exertion during floor mopping using a figure eight method

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Abstract: The aim of this study was to investigate effects of mop handle height on electromyographic (EMG) activities of the shoulder muscles and perceived exertion for the shoulder area during floor mopping using a figure eight method. An experimental study with 13 cleaners was conducted using surface EMG and category ratio (CR-10) scale. EMG activity was recorded unilaterally from the upper trapezius, infraspinatus, anterior and middle deltoid muscles. Each subject performed four trials of mopping and each trial consisted of using a different mop handle height (mop adjustment at the level of shoulder, chin, nose and eye) in randomized order. EMG data were normalized to a percentage of maximal voluntary contraction (%MVC). The muscle activities were assessed by estimating the 10th, 50th and 90th percentiles of the amplitude probability distribution function (APDF) of the EMG signals and analysed by linear mixed model analysis. Results showed that shoulder muscle activity was significantly lower when the mop handle height was adjusted to shoulder level or chin level as compared to eye level. These findings were supported by subjective ratings of exertion. It seems that mop handle height adjustment between shoulder and chin level may be recommended as a basis for figure eight mopping.

Key words: Muscle activity, Electromyography, Perceived exertion, Floor mopping, Cleaner, Shoulder

Introduction

Professional cleaning is important work that is carried out worldwide. In recent decades, the technology of cleaning tools, equipment and machines has developed[1, 2]. Nevertheless, the majority of cleaning work is still conducted manually[1]. Cleaning is physically demanding work with a high frequency of awkward working postures[3–6], repetitive movements[4], static muscular load[4, 7, 8] and lack of muscle rest[9]. Thus, cleaners have a high risk of developing musculoskeletal disorders (MSDs)[1, 10–12], such as neck and shoulder symptoms[6, 9, 12–15]. Therefore, preventive actions are needed to reduce overloading of shoulder muscles and to prevent work-related upper extremity disorders (WRUEDs).

Floor mopping takes up 35–40% of the working time in most cleaning jobs[4] and it has received much attention in the literature as a physically demanding cleaning task[2, 8, 16, 17]. Mopping is characterised by high static

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shoulder muscle load[7, 8], repetitive movements of the upper extremities[4, 7] and awkward postures of neck, shoulder and back[6, 7, 18]. Surface electromyography (EMG) has been widely used to assess the muscle activity associated with different floor cleaning methods and techniques[2, 3, 7, 8, 19]. It has been shown that wet mopping causes higher muscular and cardiorespiratory loading than dry mopping[2, 17, 20]. Earlier studies using EMG[7, 8] have found that during mopping the static load on the upper trapezius muscle exceeds the level of 2−5% maximal voluntary contraction (MVC) suggested as a threshold limit value for long-term work[21]. In addition, the trapezius muscle on the upper position arm (i.e., the hand placed higher on the mop handle) has a higher activity level than the lower position arm[2, 8, 16], regardless of the dampness of the mop and mopping direction (i.e., backward or forward)[20].

Previous research has indicated that the figure eight mopping method (i.e., moving the mop in an arc) is more strenuous than the ‘push’ method[8]. The median muscular load on the trapezius and perceived exertion were higher with the figure eight method compared to the ‘push’ method. Moreover, the figure eight method involves highly repetitive movements of the arms, with a cycle time of approximately 2 s, and large shoulder abduction movements particularly in the upper position arm[8]. It seems that regardless of the method or technique used during mopping, the shoulder muscle load is high for the hand placed higher on the mop handle[2, 8, 16, 20]. High force requirements, repetitive movements and working with the hand above shoulder level are widely recognized as work-related physical risk factors for MSDs of the shoulder[22].

Physical risk factors of floor mopping systems have been identified. Inadequacies in the design of mops have been highlighted and design modifications have also been suggested[6]. One essential issue of concern for users has been found to be an unsuitable mop height[6, 11]. Finnish survey (n=48) has found that 35% of cleaners hold the mop at shoulder level, 33% at chin level and 21% at nose level[20]. It has also been reported that for female cleaners the top of the mop was situated between standing eye and shoulder height[6]. A long-handled mop has been considered too long for shorter cleaners[6]. On the other hand, a longer mop handle allows cleaners to maintain a more upright posture when mopping[11]. In practise, telescopic mop handles are commonly used, but it seems that advice on the optimal mop handle height differs among cleaning managers, supervisors and occupational health services. The benefits of modern mop handles could be lost, if cleaners do not know how to use a mop safely. Only a limited number of studies have evaluated the effect of adjustment of mop handle on shoulder muscle load. A study of Öhrling *et al.*[19] found that in staircase mopping the shoulder muscular activity and perceived exertion were lower when an easily adjustable mop handle was used, compared to a non-adjustable mop. However, it is uncertain whether the high shoulder muscle load during mopping with a figure eight method is partly due to the use of a too-long mop handle. Thus, information about the muscular activity related to mop handle height is needed.

The aim of this study was to examine the effects of mop handle height on shoulder muscle activity of the upper position arm and perceived exertion during floor mopping with a figure eight method. EMG activities were measured from four shoulder muscles during mopping with four different heights of the mop handle. It was hypothesized that shoulder muscle activities and perceptions of exertion would differ among different heights of the mop handle.

Subjects and Methods

Subjects

A total of 13 volunteer professional cleaners (12 females and 1 male) participated in this study. The inclusion criteria were a minimum six months’ working experience as a cleaner and floor mopping as a part of cleaner’s daily routine. Exclusion criteria included a disorder in shoulder region at the time of the experiment. The study procedures were approved by the Committee on Research Ethics of the North Savo Hospital District. The study was conducted in conformity with the Declaration of Helsinki. Each subject signed an informed consent form.

Instrumentation

An aluminium telescopic mop handle and a 60 cm wide mop frame with unlocked swivel mechanism were used in this experiment. The handle could be extended to a length anywhere between 100 and 170 cm. The shaft of the mop handle was 2.6 cm in diameter. The handle grip was composed of ribbed plastic, 13.5 cm in length and 3.2 cm in diameter. The mop weighed 850 g and the dry microfiber mop (cloth) weighed approximately 120 g. The friction between the floor and the tool depends on the dampness of the mop and impacts on physical load[2]. For this reason, standardized dampness was controlled by dampening the microfiber mop with 60 ml of water.

Table 1. Electrode placements

Muscle	Electrode placement	Reference electrode
Upper trapezius	2 cm lateral to the midpoint of the lead line between the spinous process of C7 and posterolateral border of acromion[26]	C7 vertebra
Middle deltoid	Lateral aspect of the upper arm, approximately 3 cm below the acromion[27]	Acromion
Anterior deltoid	Anterior aspect of the upper arm, approximately 4 cm below the clavicle[27]	Clavicle
Infraspinatus	Approximately 4 cm below the spine of the scapula on the lateral aspect, over the infrascapular fossa of the scapula[27]	Lateral part of acromion

Table 2. Description of the maximal isometric voluntary contractions tests

Normalisation test	Test position (subjects seated in an erect posture without back support)
Flexion 125°	Shoulder flexed to 125° as resistance applied above elbow and at the inferior angle of scapula attempting to de-rotate scapula[28]
Empty can	Shoulder abducted 90° in plane of scapula, internally rotated and elbow extended. Arm abducted as resistance applied at wrist[28]
External rotation 0°	Shoulder kept in pendant position in neutral rotation with elbow flexed 90° and arm externally rotated as resistance applied at wrist[28]

Electromyographic measurements

Surface electromyographic activity was recorded unilaterally from the upper trapezius (UT), infraspinatus (IP), middle (MD) and anterior of the deltoid (AD) muscles, from the side that the subject preferred to use higher on the mop handle. These muscles were chosen for their relevance to shoulder function during floor-mopping[7, 8, 16, 23]. Further, the selection of the UT muscle was also based on earlier studies, which reported that the trapezius load might be a predictor of disorders in the neck and shoulder region[24].

Surface electrodes were applied over the muscle bellies so that they ran parallel to the muscle fibers, and reference electrodes were placed on an electrically inactive area, in accordance with SENIAM guidelines[25]. Prior to electrode placement, the skin was shaved (if required) and rubbed with alcohol over the appropriate areas in order to reduce impedance levels. A skin impedance of less than 10 KΩ measured using an ohm meter (Fluke 183, True RMS multimeter), was considered acceptable. EMG signals were obtained bipolarly using disposable Ag/AgCl-surface electrodes (Ambu Neuroline 720, Denmark), a gel area diameter of 10 mm and an inter-electrode distance of 20 mm. The electrode placement guidelines of McLean *et al.*[26] or of Cram *et al.*[27] were adopted (Table 1). A Biomonitor ME6000 (Mega Electronics Ltd, Kuopio, Finland) was used for measuring muscular activity. EMG data were collected at a sampling rate of 1,000 Hz, raw EMG signals were analogically band-pass filtered with an anti-aliasing filter (signal band-pass 8–500 Hz) and preamplified (gain: 1000, a common-mode rejection ratio CMRR of >130 dB, noise <1 μV).

It has been recommended to use more than one test to facilitate finding the maximal levels of EMG activity in order to normalize the data[28–30]. In the present study, the subject performed isometric MVC in three test positions. 'Flexion 125°,' 'empty can' and 'external 0°' tests were selected, because it has been reported that the 'flexion 125°' test maximally activates the UT, AD, MD and IP muscles, whereas the 'empty can' test maximally activates the UT, AD and MD muscles, and the 'external 0°' test highly activates the IP muscle[28]. The test positions are described in Table 2. Each contraction was performed against manual resistance for 5 s with 1 s to reach maximum, sustained maximum for 3 s and 1 s to gradual release contraction. Three repetitions of each test were performed, with a rest interval of 30 s between repetitions[28, 30] and a rest period of 2 min prior to new test. During tests, standardized verbal encouragement was given to the subjects.

Experimental protocol

The experiment included three phases. At the beginning, the subjects filled in a questionnaire; including questions about individual characteristics (e.g. age, dominant hand), experience in cleaning work, and subjectively perceived symptoms and pain in their shoulder region. The intensity of perceived pain was assessed by means of a Numeral Rating Scale (NRS-11)[31]. Anthropometric measurements consisted of body weight, height and Body Mass Index (kg/m^2). Anthropometric dimensions of the upper limbs were

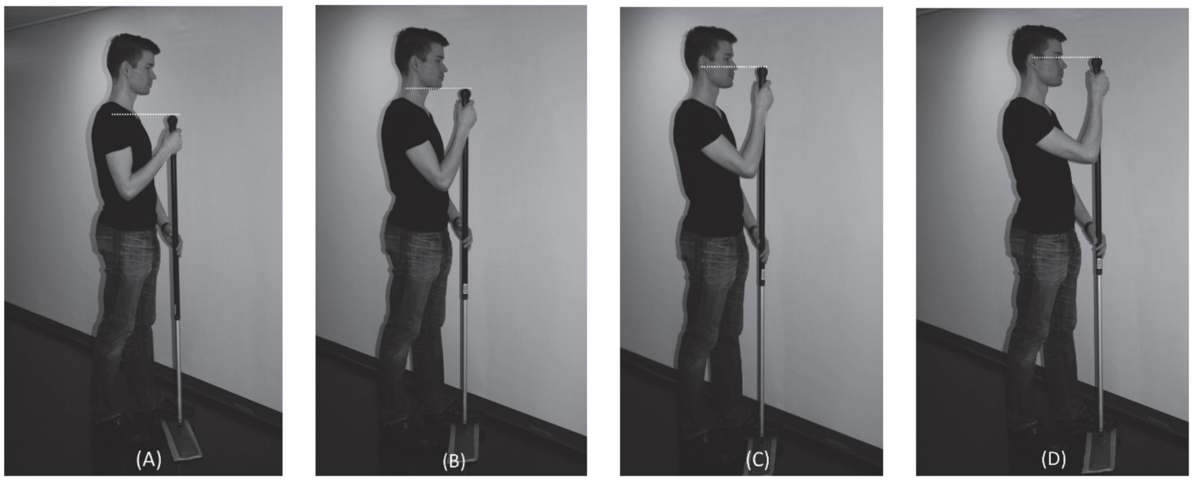

Fig. 1. Four different mop handle heights were used in this experiment.
The subject stood in a neutral position, gripped the mop handle with the preferred hand and placed the opposite foot on the top of mop frame. The top of the mop handle was adjusted to four levels as follows: (A) shoulder level: slightly below the lateral border of clavicle, (B) chin level: in line with chin, (C) nose level: in line with the apex of the nose and (D) eye level: in line with the corner of the eye.

also assessed[32]. Subjects were guided in the use of Borg's category ratio scale (CR-10 scale)[33], which is an acceptable approach to quantifying muscle force and fatigue[34]. In the second phase of the experiment, subjects practiced each MVC test and after the actual MVC test recordings there was a rest period of 5 min before beginning the mopping trials.

In the third phase of the experiment, the subjects mopped the floor surface of a 20 m long and 1.79 m wide corridor back and forth once. Subjects walked forward while they moved the mop from side to side in a figure eight pattern. The subjects were encouraged to use their habitual style and normal working rhythm, and they were allowed to practice before the first trial. Each subject performed four trials of mopping and each trial consisted of using a different mop handle height (Fig. 1) in randomized order. The mop handle heights were selected according to prior studies[6, 20] and easily recognisable anatomical landmarks were chosen for practical adjustments. Breaks of 5 min were given between the trials to prevent the cumulative effect of local muscle fatigue. At the end of each trial, the subjects were asked to verbally rate their level of perceived exertion for shoulder area using CR-10 scale from 0 to 10: 0 for 'nothing at all' and 10 for 'an extremely strong' exertion[33]. After trials, the subjects were asked open-ended questions, including the subjective preference for the four heights of the mop.

EMG data processing and analysis

At first, the EMG signals were band-pass filtered (5th order Butterworth, 20–400 Hz pass-band), and the few high-amplitude artefacts were removed using spline interpolation. Root mean square (RMS) amplitudes were calculated using a window length of 250 ms.

The RMS amplitudes of the mopping trials were normalized according to isometric MVC tests such that 100%MVC value corresponds to the highest value obtained during the three MVC tests, individually for each muscle and each subject.

Next, the amplitude probability distribution function (APDF) for RMS amplitudes was assessed for each time period when the actual mopping of 20 m long corridor took place. The 10th, 50th and 90th percentiles of the APDF, expressed as %MVC, for the four muscles (UT, MD, AD, IP) were calculated for each subject and for each mopping trial. These percentiles are denoted by APDF10, APDF50 and APDF90 and represent static, median and peak activity levels[21], respectively. All signal processing and analysis was performed using the MATLAB R2014a (The MathWorks Inc., Natick, MA, USA) environment.

Statistical analyses

Statistical analyses were performed using SPSS version 22.0 (SPSS Inc., Chicago IL, USA). Descriptive statistics (median, mean, standard deviation, range, quartiles) were calculated. The APDF parameters were logarithmically transformed due to the skewness of the distribution. After logarithmic transformation, the normality was tested using the Kolmogorov-Smirnov -test. The linear mixed model was used for statistical analysis to examine the differences in the shoulder muscle activities among different mop handle heights. The Sidak method was performed for multiple comparison. Each logarithmically transformed EMG parameter (APDF10, APDF50 and APDF90) was used as a dependent variable and analysed separately. The mop handle heights (i.e., shoulder, chin, nose and eye level) and muscles (i.e., UT, IP, MD, AD) were used as fixed factors in all analyses. The distribution of residuals was controlled in the analyses. Furthermore, the non-parametric Friedman's test was used to examine the differences in perceived exertion among different mop handle heights. In all tests, $p<0.05$ was considered as statistically significant.

Table 3. Means, standard deviations (SD) and ranges of subjects' demographic, anthropometric and work experience characteristics (n=13)

Characteristic	Mean (SD, range)
Age (yr)	41 (14.6, 21–58)
Experience in cleaning work (yr)	11 (11.4, 1–29)
Height (cm)	163 (8.1, 149–180)
Weight (kg)	70 (9.6, 52–83)
Body Mass Index (kg/m²)	26.5 (4.0, 20.2–33.9)
Shoulder height (cm)[a]	135.5 (7.0, 123–150)
Shoulder-elbow length (cm)[a]	33.8 (2.3, 29.9–37.1)
Elbow fingertip length (cm)[a]	43.5 (1.9, 39.9–46.5)

[a]The anthropometric data for the upper limb of the 13 subjects with reference to traditional anatomical landmarks[32)]

Results

The mean age of the subjects was 41 yr (SD 14.6). All except one of the subjects were dominant right-handed. Twelve out of 13 subjects used their right hand higher on the mop handle during the floor mopping experiment. Demographic, work experience and anthropometric data of the subjects are shown in Table 3. In the month prior to the experiment, symptoms in the shoulder region had been experienced by 10 subjects and the mean intensity of the pain was 4.6 (range 1–8) using the NRS-11 scale. The measured mean heights of the mop were as follows: shoulder level 136 cm (SD 6.8), chin level 143 cm (SD 8.1), nose level 151 cm (SD 7.9) and eye level 155 cm (SD 7.6).

Muscle activities

Descriptive data of the EMG parameters are presented in Table 4. The analysis showed that the height of the mop handle had a statistically significant effect on log (APDF10) ($p<0.001$), log (APDF50) ($p=0.003$) and log (APDF90) ($p=0.026$) parameters. The muscles had also statistically significant effect on log (APDF10), log (APDF50) and log (APDF90) parameters ($p<0.001$ for each parameter).

APDF10 values, representing static activity level,

Table 4. Median, mean and standard deviation (SD) values of APDF10, APDF50 and APDF90 EMG parameters during floor mopping with four different height of the mop

Muscle	Shoulder level Median (mean ± SD)[a]	Chin level Median (mean ± SD)[a]	Nose level Median (mean ± SD)[a]	Eye level Median (mean ± SD)[a]
Upper trapezius				
APDF10	1.28 (1.60 ± 1.26)	1.29 (1.78 ± 1.61)	1.87 (2.32 ± 1.53)	1.87 (3.23 ± 3.52)
APDF50	3.24 (3.94 ± 2.49)	3.40 (4.45 ± 2.93)	5.45 (5.76 ± 2.63)	5.87 (7.45 ± 4.93)
APDF90	6.43 (7.72 ± 4.61)	7.83 (9.38 ± 5.58)	10.30 (11.12 ± 4.59)	12.70 (13.58 ± 6.60)
Infraspinatus				
APDF10	2.59 (3.07 ± 1.70)	2.55 (3.20 ± 1.85)	2.77 (3.53 ± 2.09)	3.50 (4.06 ± 2.32)
APDF50	4.44 (4.96 ± 2.37)	4.27 (5.13 ± 2.38)	4.54 (5.76 ± 2.66)	5.82 (6.86 ± 3.21)
APDF90	8.30 (8.83 ± 3.59)	7.98 (8.61 ± 3.11)	8.36 (9.28 ± 3.58)	9.25 (10.76 ± 4.41)
Anterior deltoid				
APDF10	1.30 (1.50 ± 0.97)	1.15 (1.53 ± 1.15)	1.25 (1.86 ± 1.66)	2.28 (2.44 ± 1.93)
APDF50	3.05 (3.32 ± 2.07)	3.47 (3.69 ± 2.85)	3.49 (4.57 ± 3.92)	4.97 (5.45 ± 4.01)
APDF90	6.68 (6.40 ± 3.69)	5.73 (6.65 ± 5.12)	7.75 (8.68 ± 6.97)	9.83 (10.85 ± 7.60)
Middle deltoid				
APDF10	0.60 (1.23 ± 1.52)	0.65 (1.11 ± 1.13)	0.74 (1.35 ± 1.21)	0.90 (1.27 ± 0.90)
APDF50	2.05 (3.59 ± 2.59)	1.90 (3.12 ± 2.10)	2.36 (3.13 ± 2.18)	2.90 (3.14 ± 1.81)
APDF90	4.84 (7.44 ± 4.36)	4.88 (6.22 ± 3.38)	4.45 (5.56 ± 3.37)	5.40 (5.67 ± 3.09)

[a]With non-log transformed data. 10th, 50th and 90th percentiles of Amplitude Probability Distribution Function (APDF) of EMG from the upper trapezius, infraspinatus, anterior and middle deltoid muscles. Units are in terms of percentage of maximum voluntary contraction (MVC).

Table 5. Multiple comparisons of logarithmically transformed EMG values among four different heights of mop during floor mopping

Height of the mop handle[a]	log (APDF10)[b]	p^d	log (APDF50)[b]	p^d	log (APDF90)[b]	p^d
	Mean difference[c] (95% CI)		Mean difference[c] (95% CI)		Mean difference[c] (95% CI)	
A vs. B	–0.006 (–0.115, 0.102)	1.000	–0.009 (–0.121, 0.104)	1.000	0.003 (–0.107, 0.113)	1.000
A vs. C	–0.096 (–0.204, 0.013)	0.113	–0.068 (–0.181, 0.045)	0.502	–0.032 (–0.142, 0.078)	0.969
A vs. D	–0.166 (–0.274, –0.57)	**<0.001**	–0.142 (–0.254, –0.029)	**0.006**	–0.109 (–0.219, 0.001)	0.054
B vs. C	–0.090 (–0.198, 0.019)	0.163	–0.059 (–0.172, 0.053)	0.657	–0.035 (–0.145, 0.075)	0.953
B vs. D	–0.160 (–0.268, –0.051)	**0.001**	–0.133 (–0.245, –0.020)	**0.012**	–0.112 (–0.222, –0.002)	**0.044**
C vs. D	–0.070 (–0.178, 0.039)	0.429	–0.073 (–0.186, 0.039)	0.410	–0.077 (–0.187, 0.033)	0.332

[a]Mop height adjustment: A=shoulder level, B=chin level, C= nose level, D= eye level
[b]10th, 50th and 90th percentiles of Amplitude Probability Distribution Function (APDF) of shoulder muscle (upper trapezius, anterior and middle deltoid, infraspinatus) activity parameters
[c]Mean difference in logarithmically transformed %MVC (percentage of maximal voluntary contraction) values
[d]Linear Mixed Model

ranged from 0.2% MVC to 13.7% MVC. In pairwise comparisons, log (APDF10) values were statistically significantly higher when the mop handle height was adjusted to eye level as compared to shoulder level (p<0.001) or chin level (p=0.001) (Table 5).

APDF50 values, representing median activity level, ranged from 0.6% to 21.9% MVC. In pairwise comparisons, log (APDF50) values were statistically significantly higher when the mop handle height was adjusted to eye level compared to shoulder level (p=0.006). The muscle activities were also statistically significantly higher at eye level compared to chin level (p=0.012) (Table 5).

APDF90 values, representing peak activity levels, ranged from 1.1% to 31.9% MVC. Log (APDF90) values were statistically significantly higher at eye level compared to chin level (p=0.044). However, the difference was not statistically significant between shoulder level and eye level (Table 5). There were no statistically significant differences detected in any of the EMG parameters between shoulder level and chin level. Similarly, the nose level showed no statistically significant difference with respect to other mop handle heights (Table 5).

There were statistically significant differences in muscle activity levels among the four shoulder muscles. In log (APDF10), muscle activity was statistically significantly higher (p<0.001) for the IP muscle than for the UT, AD and MD muscles. In log (APDF50) and log (APDF90), muscle activity levels were also statistically significantly higher for the IP muscle than for the MD and AD, and muscle activity levels were statistically significantly higher for the UT muscle than for MD and AD muscles (p<0.001 for each muscle). There was no statistically significant difference between the IP and UT muscles. The MD muscle had the lowest activity level in each EMG parameter.

Subjective assessment

The perceived exertion (CR-10) ratings of the floor mopping ranged from 0.5 (‘extremely weak’) to 5 (‘heavy’). Subjects rated mopping exertion as ‘very weak’ (median 1) for the shoulder area when the mop handle height was adjusted to chin level. Mopping was considered ‘weak’ (median 2) at shoulder level and ‘moderate’ (median 3) both at nose level and eye level (Fig. 2). The analysis showed that less exertion was assessed when the mop was adjusted to chin level compared to nose level (p=0.011). Similarly, less strain was found when the mop was adjusted to chin level compared to eye level (p=0.005). With regard to subjective preference for mop height, the chin level was most preferred by 10 out of 13 subjects. Common reasons given were comfort and less strain on upper arm.

Discussion

This study of 13 cleaners investigated the effects of four different mop handle heights on shoulder muscle (i.e., UT, IP, MD, AD) activity and perceived exertion of shoulder

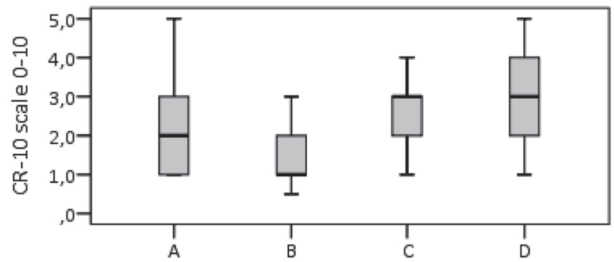

Fig. 2. Minimum, maximum, median and quartiles of perceived exertion during mopping with four different heights of the mop.
Mop adjustments: A= shoulder level, B= chin level, C= nose level, D= eye level.

area during a standardized floor mopping task. Results of this study supported the hypothesis that there were differences in shoulder muscle activities and perception of exertion among different mop handle heights.

Our study showed that shoulder muscle activation levels were similar when the mop handle is adjusted to the shoulder and chin level. As the height of the mop handle increased, a trend of increasing EMG activities was observed, and muscle activation levels were highest when the mop handle was adjusted to eye level. These results might be due to some extent to increased shoulder flexion movement, because it has been demonstrated that the activity of DA, IP and UT muscles steadily rises as the degree of forward flexion increases, whereas the MD muscle is not very active in this movement[35]. Similarly, shoulder and scapular muscle activities have been shown to increase during tasks that require large shoulder and scapular movements[36, 37] or shoulder stability[37]. Mopping also requires large shoulder movements[7, 16] and a large amount of stabilization in the shoulder[7]. Thus, the deltoid and scapular muscles may be more active in order to maintain the position of the arm and scapula with rising abduction levels during continuous movements[35]. One can postulate that this may also explain our results showing increased muscle activities at greater mop handle heights. However, MD muscle activity levels were low regardless of the height of the mop. This finding was surprising since the arms are constantly abducted during mopping[7, 8, 16]. One potential explanation for the low activity level of the MD muscle in this study may be the lower abduction angles of the shoulder, because the MD muscle is not an effective abductor until at higher angles[35]. It seemed that less favourable wrist postures did compensate for wide abduction movements of the shoulders. However, postural analysis was not used in the present study. Therefore, future studies should analyse synchronously obtained EMG and motion data of the upper limbs with different mop handle heights.

Our study examined short-term effects of mopping. Consequently, we cannot explain factors associated with long-term changes in shoulder muscles. However, it seems that median and peak activity levels in this study were lower in comparison with Jonsson's limit values[21]. It has been suggested that the static load level for continuous work for one hour or more should not exceed 2% MVC and must not exceed 5% MVC[21]. In this study, the static level for the shoulder muscles would be considered high if mopping was performed for prolonged periods of time. The mean muscle activity of the UT, IP and AD exceeded the lower limit (2%) for static load, in particular when the mop was adjusted to eye level. Muscle activities were significantly lower for mop adjustments at shoulder and chin level. On that account, it is recommended to use a lower adjustment of the mop. Moreover, the reduction in the mean muscle activity was greatest for the UT muscle when mop handle height was changed from eye level to shoulder level. The results of previous studies supported a causal relationship between prolonged static loads and high level of static contractions and neck-shoulder pain[38]. In addition, high static load of the trapezius muscle is associated with neck-shoulder disorders and it has been shown that even a static level below 1% MVC may be harmful[24]. Therefore, reducing the activity of the UT muscle may be one means of preventing MSDs in the neck-shoulder area.

In this study, the 10th, 50th and 90th percentiles of UT muscle activities seemed to be markedly lower than previously reported[7, 8, 16, 39]. However, direct comparisons with other research results must be conducted with caution due to methodological differences. EMG results may differ due to electrode placement and MVC procedures. One potential explanation for the lower muscle activity levels in the present study may be lighter mop materials and the amount of water used in the mop[2]. Majority of cleaners (85%) in this study had received ergonomic training, which may somewhat explain the lower muscle activities. In addition, these differences may be explained by the various mopping environments and tasks. Moreover, the inter-individual variations in EMG activity levels seemed to be high even if the mopping task was similar. Individual differences in mopping style were observed, which accounts for part of the total variation. Methodological factors may explain some of the variation[40]. However, in this study each cleaner served as their own control so the effect of individual differences on results is probably minor.

A strength of this study is the utilization of both subjective and objective measurements. The use of self-reported measures of exertion of the shoulder area increases the understanding of the effect of physical workload on the musculoskeletal system. Prior research has demonstrated a positive correlation (r=0.99) between ratings with CR-10 scale and objective measure of exerted force (RMS values)[34]. As our results indicate, lower mop handle heights led to decreased shoulder muscle activation. Cleaners also rated lower mop handle heights, the chin level adjustment in particular, as less strenuous for their shoulder area. These lower ratings of exertion can probably be explained by the fact that the postures were more convenient, because cleaners were able to work with their arms at a lower level without elevating their shoulders. Similarly, with regard to staircase cleaning the favourable impact of adjustment of the mop on perceived effort and muscular load has previously been reported[19].

This study has some limitations. First, the sample size was small to be able to generalize the results to the entire population of cleaners, but it was similar to that of previous studies[7, 8, 16, 23, 39]. Second, the same mop cloth was used in all four trials, because the weight of available dry mop cloths was not precisely identical. Therefore the dampness of the mop cloth may have been somewhat different in each trial, because the moistening (60 ml of water) was performed before the first trial. The weight of the mop cloth had decreased an average of 9.5 g over the course of the experiment. Thus, the impact on muscle demand of the loss of mop cloth weight due to moisture reduction was probably minor. Moreover, the order of the mop heights was randomized to eliminate systematic bias. Third, this study did not evaluate muscle activities in diverse mopping environments. It is known that buildings and work areas are not designed and furnished to be easy to clean[1, 12]. Thus, the mop handle height should be tailored not only to the individual, but also to the task in question. Despite these limitations, this study revealed that muscle activity levels were affected by the change in height of the mop handle. Information obtained in this study can be used as a basis for the selection of appropriate mop handle height. Hence, further study is suggested in order to record the EMG and postures bilaterally (i.e., both arms) for longer durations in more challenging environments.

In conclusion, the present study demonstrated that height of the mop handle had an impact on the activation level of the shoulder muscles and perceived exertion of the shoulder area. Increased mop handle height was associated with higher muscle activity levels. These findings were supported by subjective perceptions of exertion. Therefore, in order to reduce muscle demand, a mop height adjustment between chin and shoulder level may be recommended as a basis for floor mopping with a figure eight method. The results of this study may be useful for cleaners in assisting them to optimize the use of the mop and reduce risks of WRUEDs resulting from overuse of the shoulder muscles. Further, these results could be used in occupational health care, as well as by cleaning supervisors and managers responsible for ergonomic guidance (e.g. work orientation sessions for new employees). In addition, the results might benefit cleaners who should avoid unnecessary load on account of shoulder impairments.

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