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ORIGINAL ARTICLE

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Work load during floor cleaning. The effect of cleaning methods and work technique

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Abstract Cardiovascular and muscle load levels were evaluated during floor cleaning. A group of 12 experienced female cleaners participated in the study. Of the subjects 6 used a mopping method and 6 a traditional scrub and cloth method. Heart rate, oxygen consumption, rating of perceived exertion, electromyography from the trapezius muscle and video recordings were obtained during floor cleaning. With respect to relative heart rate and oxygen consumption the two groups did not differ. The results revealed a high cardiovascular load corresponding on average to 53% of the individual maximal oxygen uptake. In addition 65% of the observed period was spent with the back in a position forward flexed more than 20°. The time spent in extreme forward back flexion was shorter for the mopping group. Both groups exhibited high static, median and peak shoulder muscle load levels of 10%, 25% and 54% maximal voluntary contraction, respectively. At the same time, however, the mopping group tended to have a higher shoulder load than the group using the scrub and cloth method. Furthermore, electromyographic signs of fatigue in the trapezius muscle indicated a more stereotype activation of the shoulder muscles during mopping than during scrubbing. Based on these results, it was concluded that mopping cannot be recommended as less strenuous than scrubbing.

Key words Muscle fatigue · Kinematics · Oxygen uptake · Cleaners · Electromyography

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Introduction

In Denmark work related musculo-skeletal disorders are frequently reported for persons engaged in occupational cleaning tasks. In 1985 cleaning was among the five trades most frequently associated with work related shoulder/neck disorders, tendovaginitis, and low back pain (Danish Working Environment Service 1989). Since then the problem has increased. The years from 1984 to 1991 have exhibited a 400% rise in reports of work related musculo-skeletal disorders for subjects engaged in cleaning tasks. Over the same period the overall increase in general reports of work related disorders has been 85% (Steensberg 1993). In accordance with these data, a questionnaire survey among 1,166 women showed that the 1-year prevalence of musculoskeletal disorders was significantly higher among cleaners than in an age-matched reference group of Danish female wage earners (Nielsen 1995).

Occupational cleaning is mainly a manual task with very little mechanization. About 130,000 people in Denmark are presently employed in this occupation and most of them (85%) are women. During the last decades efforts to improve efficiency have led to the introduction of many new cleaning methods. As floor cleaning is one of the most time-consuming components of cleaning most of the developments of new tools and methods has focused on this task. The general trend has been a change from the traditional scrub and cloth method to a variety of newly developed mopping methods.

During scrubbing, the scrubber is moved forward and backward, whilst during mopping, the mop is moved in a butterfly shape. Mopping systems have been introduced to decrease the physical load and to save time. In a recent questionnaire, involving 1,166 Danish cleaners, 21% reported that they used the new technique exclusively, 28% used the mopping as well as the scrub and cloth method, and 45% stated that they used the scrub and cloth method exclusively (Nielsen

1995). Until now, however, there has been no research to evaluate whether the actual work load during mopping is lower than during scrubbing. Furthermore, cleaning work is generally described as being physically heavy work. For the often elderly female cleaners this problem is attenuated by an age related decrease in both the muscle strength and cardiovascular capacity (Asmussen and Heebøll-Nielsen 1962; Asmussen and Molbech 1959).

It was thus a principal aim of the present study to quantify cardiovascular and muscle load during floor cleaning in relation to the capacity of the cleaners and to evaluate the beneficial effect of introducing new mopping methods as a means of reducing the overall physical work load.

Methods

Subjects

From a wide-ranging study by questionnaire on municipal cleaning, two public schools with different floor cleaning methods were selected (Nielsen 1995).

A each school 6 women were randomly selected and consented to participate in the study after being informed about the conditions of the experiment. Mean length of service in the present employment was 144 months with a range from 2 to 342 months. There were 3 subjects who had less than 12 months service in the present job, but none of them had less than 6 years of experience as cleaners in previous employment. The mean age of the 12 subjects was 52 years with a range from 37 to 60 years. Over the previous 12-month period trouble in the neck and shoulders had been experienced by 7 and 8 subjects, respectively. This was similar to the results of the large questionnaire study which also showed a high degree of musculoskeletal complaints among cleaners (Nielsen 1995). The characteristics of the subjects are shown in Table 1.

Their weekly working hours at the schools were 20 h. Of the women 6 used the cloth and scrub method and the other 6 used a version of the mopping method called minimop. All the subjects used a cleaning cart where the water bucket was placed. The hand and arm used in the upper position (UP) of the handle are termed UP-hand and -arm, the hand and arm used in the lower position (LP) of the handle are termed LP-hand and -arm. In the scrubbing group, the dominant hand was the right hand and they all used the right hand as the UP-hand. In the mopping group 5 subjects had the right hand as the dominant hand and 1 was left-handed. The left-handed and one of the right-handed subjects used the left hand as the UP-hand.

Protocol

The protocol included 2 measurement days. On day 1, body mass, height and some other anthropometric measurements were taken. Each subject was then followed during the working day. Load on the trapezius muscle was evaluated by electromyographic (EMG) recording during work periods. Heart rate (HR) and oxygen uptake ($\dot{V}O_2$) were recorded during a 15-min period of uninterrupted floor cleaning and the subjects were videotaped. The $\dot{V}O_2$ measurement was followed by a record of the subjective rating of perceived exertion (RPE). To assess EMG signs of muscle fatigue a standard test contraction was performed before and within 1 min of the end of the work period.

On the 2nd experimental day individual maximal oxygen uptake ($\dot{V}O_{2max}$) was estimated by a two-point submaximal cycle ergometer test performed prior to the normal working day. Subsequently the amount of forward flexion of the back during floor cleaning was evaluated by an inclinometer.

During all measurements the subjects cleaned their usual area in the school and followed their normal working routines. Due to the measurements, their working hours were up to 1 h shorter than normal.

$\dot{V}O_2$ and HR

The $\dot{V}O_2$ was measured with the Oxylog (PM Morgan Ltd), which is in other studies has proved to be well suited to field measurements and in good agreement with other methods (Louhevaara and Ilmarinen 1985). The HR was continuously measured precordially by a Sportstester PE 300 (Polar Electro). During work the portable Oxylog was mounted on the back of the subject and $\dot{V}O_2$ was read from the Oxylog every 2nd min. For each subject the average value was calculated for a 15-min period of typical floor cleaning.

The $\dot{V}O_{2max}$ were estimated for each subject by extrapolating the relationship between HR and $\dot{V}O_2$ measured during the 6th min at each work level of the cycle test to the estimated maximal HR (220 minus age). The relative load was expressed as either the absolute $\dot{V}O_2$ during work as a percentage of the subjects $\dot{V}O_{2max}$ or as the HR during work (minus resting HR = 70) as a percentage of the estimated age-corrected maximal heart rate (minus resting HR = 70; Asmussen and Hemmingsen 1958).

Rating of perceived exertion

The RPE was estimated using the RPE scale of Borg (1970) which was presented to the subject as near as possible to the time of the $\dot{V}O_2$ measurements.

Table 1 Anthropometric data and maximal voluntary contractions (MVC) of the six women using the mopping method and the six women using the scrubbing method. None of the observed differences between the two groups were significant

		Age (years)	Body mass (kg)	Height (cm)	Arm length (cm)	Upper arm length (cm)	Hand length (cm)	Shoulder width (cm)	Maximal shoulder lift (N)
Mopping group	Mean	54	74	161	71	34	18	36	278
	Range	37–60	63–93	156–164	67–73	32–35	15–20	33–41	200–410
Scrubbing group	Mean	49	69	158	71	34	18	37	360
	Range	43–55	53–90	149–165	68–73	31–39	17—20	35–39	170–480

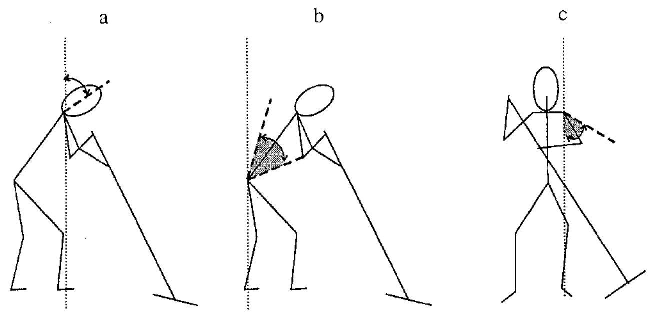

Fig. 1 *Stick figures* illustrating the definitions of the angles between body segments and vertical. Vertical is shown as a *dotted line*. The *shaded area* represent the range between the two extreme positions during one work cycle (angular amplitude) and the mean angle during a fundamental work cycle is calculated as the mean of the two extreme positions. In **a** the neck flexion is shown, in **b** the back flexion and in **c** the upper arm abduction

Kinematics

Work postures and work technique were evaluated from a video-based kinematic analysis. The subjects were video-recorded (Panasonic MS90 S-VHS Camcorder) while performing the floor cleaning. Recordings of the subject were made from left side, right side and frontally. Abduction of left and right upper arms were measured from the frontal perspective, and flexion of the back and neck from the sagittal perspective (Fig. 1.) The time to complete ten fundamental work cycles was measured twice for each subject.

Co-ordinates for the joint centres of the wrists, elbows, shoulders, L4-L5 and the midhead were digitized using the Peak Performance System (Peak Performance Technologies). From the frontal recording, the co-ordinates of the joint centres were obtained with a frequency of 50 Hz during a typical fundamental work cycle for each subject. From these data abduction velocity of the upper arms was calculated. Abduction was defined as the angle between the upper arm (between elbow point and shoulder point) and the line of gravity through the shoulder point, positive values representing abduction and negative values abduction.

From the sagittal view only video pictures of the two extreme positions, defined as the two pictures where the tool was furthest away and closest to the subject, respectively, were analysed during two typical fundamental work cycles. Forward flexion of the back was defined as the angle between the back segment (between L4-L5 and vertebra prominence) and the line of gravity through L4-L5, positive values representing flexion and negative values extension. Values for flexion of the neck were calculated both as the head segment (vertebra prominence to the ear channel) in relation to the line of gravity through vertebra prominance and as the flexion angle corrected for the corresponding back flexion. Individual values are presented as average values from two fundamental cycles at least 10 min apart.

A direct measurement of the forward flexion of the back during floor cleaning was obtained using an inclinometer (Nickometer). The inclinometer consisted of a pendulum potentiometer, measuring the position of the back in relation to the line of gravity. Recorded signals were A-D converted and stored in a portable microcomputer mounted in a small harness on the back of the subject. The signals from a 10-min period of undisturbed floor cleaning were analysed and the results given as a percentage of the total analysis time with the back positioned in 10° intervals of forward flexion.

Electromyography

The myo-electric activity of the descending part of the trapezius muscle was picked up by bipolar disposable Ag/AgCl surface electrodes (Medicotest). The electrodes were placed in an area approximately midway between C7 and the acromion with a centre-to-centre distance of 20 mm. Before electrode placement, the skin area was dry shaved and rubbed with alcohol. The EMG signals were amplified and transmitted by a telemetric system (Medinik IC 600 G) and stored on magnetic tape (Brüel and Kjaer, type 7003, bandwidth DC to 1,000 Hz). The bandwidth in the telemetric system was for the recording of the work place EMG 10–1,800 Hz and for the test contractions 2–1,800 Hz.

The muscle load during work was evaluated by estimating the amplitude probability distribution function (APDF) of the EMG (Jonsson 1978). The APDF were calculated for each subject based on EMG recordings obtained during floor cleaning. The transformation of EMG results to relative force (% maximal voluntary contraction, %MVC) was based on a piece-wise linear EMG-force model obtained from a series of maximal and sub-maximal isometric contractions for each subject. The MVC of the shoulder muscles was determined as the highest force value during three attempted bilateral shoulder elevations following standard test procedures (Caldwell et al. 1974). Following a rest period the subjects performed short isometric contractions at load levels corresponding to 20%–60% MVC. During all isometric contractions, the EMG level from the descending part of the trapeziu muscle was simultaneously recorded. The EMG recordings over 2 s from the maximal and submaximal contractions, respectively, were used for analysis. Signals were root mean square (rms)-detected (time constant 100 ms) and digitized at a sampling rate of 128 Hz. Each sample was divided in two sub-periods of 1-s duration and the EMG signal amplitude calculated and expressed as a mean of the two subsequent 1-s periods.

From the work place recordings 3 min of EMG, obtained during floor cleaning and free from visible noise and movement artefacts, were analysed. Following rms detection (segment length 250 ms) and A-D conversion as described above, individual APDF of the myoelectric signal and corresponding relative force of contraction were calculated by computer.

Development of muscle fatigue was evaluated by analysing the EMG signals obtained during test contractions performed pre and post-working hours for changes in EMG amplitude and frequency content. Briefly, the subjects attempted a bilateral shoulder lift corresponding to a force development of 100 N. The EMG signals were recorded continuously for 2 s after target force stabilization. During signal processing the recorded EMG was low-pass filtered (450 Hz), digitized at a sampling rate of 2,048 Hz and subdivided into four periods of 500-ms duration. The power density spectrum function for each 500-ms period was obtained using a fast Fourier transformation technique giving a 512-points spectrum and a frequency resolution of 2 Hz. The mean power frequency (MPF) was calculated by computer (Kwatny et al. 1970) and used as a single number estimate to characterize the power density spectrum. Finally, the resultant MPF from the test contraction was calculated and expressed as a mean of the four subsequent 500-ms periods. Simultaneously the corresponding EMG signal amplitude was calculated as the rms value of each sample taken directly from the digitized values in the time domain.

Force recordings

The subjects were seated in a specially designed chair in which a standardized body position could be maintained. All measurements were performed with elbows straight and arms hanging vertically without support. During test contractions, force in an attempted bilateral shoulder elevation was exerted on two small, cushioned plates located above the shoulder height. Force output was measured by means of an electronic load cell (Bofors) mounted in the plate corresponding to the dominant arm side.

Statistics

Differences between the mopping and the scrubbing group were tested with the Mann-Whitney nonparametric test. The Wilcoxon matched-pairs signed rank test was used to test differences in before and after values for the same subject. All statistical comparisons were tested with a significance level of $P = 0.05$.

Results

Oxygen uptake

Values for absolute and relative $\dot{V}O_2$ during floor cleaning are presented in Fig. 2 together with the corresponding HR and RPE data. There were no significant differences in these parameters between subjects with regard to working method. Mean relative $\dot{V}O_2$ for the whole group was 53% (range 31%–65%) $\dot{V}O_{2max}$ and similar to the relative workload calculated from the HR results. A significant relationship was found between relative $\dot{V}O_2$ and predicted maximal aerobic power (Fig. 3). The RPE among the cleaners was rated as "somewhat hard" on the Borg scale.

Work postures and movements

The video analyses revealed considerable individual differences in working movements and techniques. In spite of individual differences, all 12 subjects worked with fundamental work cycles shorter than 2 s. For the two methods there was no significant difference in mean fundamental cycle time [scrubbing 1.0 (range 0.8–1.6) s mopping 1.4 (range 1.1–1.8) s].

Kinematic values were calculated and are presented as the mean of the two extreme positions and the angular amplitude between these during a fundamental work cycle. Table 2 shows the mean shoulder abduction and the angular amplitude during a fundamental cycle for the UP and LP-arm. For both methods a significantly larger mean abduction was found for the UP-arm compared to the LP-arm. For the mopping method, there was no difference in the angular displacement between the UP- and LP-arm during a fundamental cycle. This was significantly different from the scrubbing method, where the LP-arm had a significantly smaller angular displacement than the UP-arm. During a scrubbing cycle the UP-arm reached a signicantly higher peak velocity than during mopping (Table 2).

Table 3 shows the mean neck flexion in relation to the line of gravity and the position of the back, respectively. No angular displacement is given because the head was held at a nearly constant angle in relation to the floor during the whole fundamental cycle. There was no significant difference between working methods.

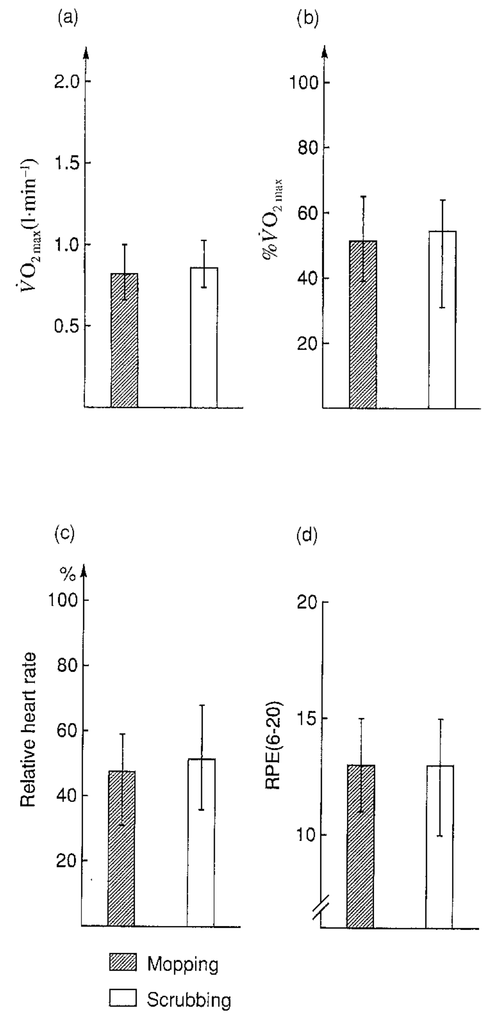

Fig. 2 Absolute oxygen uptake ($\dot{V}O_2$) (**a**), relative oxygen uptake (%$\dot{V}O_{2max}$) (**b**), relative heart rate (**c**), and rate of perceived exhaustion (*RPE*) (**d**) for the mopping group ($n = 6$) and the scrubbing group ($n = 6$). *Vertical bars* indicate range

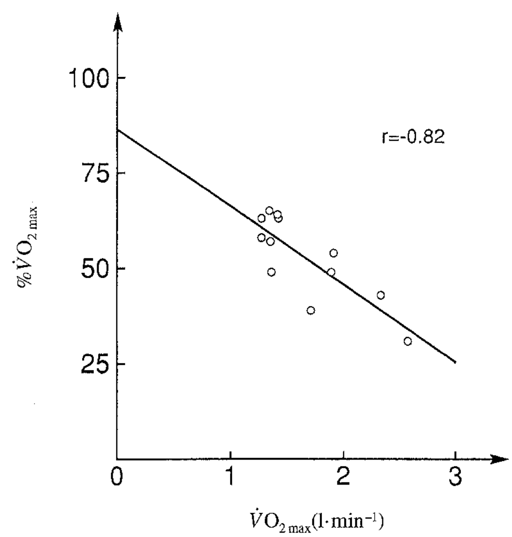

Fig. 3 Relative oxygen uptake (%$\dot{V}O_{2max}$) during floor cleaning in relation to predicted maximal aerobic power ($\dot{V}O_{2max}$)

Table 2 Kinematic data of the arm in upper position (*UP*) on the handle and the arm in lower position (*LP*) on the handle during a single fundamental work cycle obtained from the frontal video recording. Negative values correspond to adduction

		Shoulder abduction					
		Mean abduction angle (°)		Amplitude of abduction (°)		Peak abduction velocity (°·s^{-1})	
		UP-arm	LP-arm	UP-arm	LP-arm	UP-arm	LP-arm
Scrupping group	Mean	40[b]	4	46[b]	20	182[a]	90
	Range	24–59	−8–13	21–64	9–43	144–216	53–141
Mopping group	Mean	37[b]	1	40	35[a]	114	117
	Range	25–46	−11–13	26–76	19–48	70–139	76–190

[a]Significant difference between the two cleaning technique, [b]significant difference between the *UP*- and the *LP*-arm ($P < 0.05$)

Table 3 Neck flexion during a single work cycle obtained from the sagital video recording. Values are given as the angle in relation to the line of gravity and the forward flexion of the head segment in relation to the low back flexion

Reference		Neck flexion	
		Vertical (°)	Low back (°)
Scrubbing group	Mean	37	14
	Range	20–56	3–28
Mopping group	Mean	51	23
	Range	36–65	3–38

Table 4 Back flexion in relation to vertical during a single fundamental work cycle obtained from the sagital video recording.

		Back flexion	
		Mean flexion (°)	Amplitude of movement (°)
Scrubbing group	Mean	27	18[a]
	Range	4–35	9–29
Mopping group	Mean	28	7
	Range	18–41	2–15

[a]Significant difference between mopping and scrubbing

Table 4 shows the mean forward flexion of the back and the angular amplitude during a fundamental work cycle. There was no difference between the two groups regarding mean forward flexion, but the mean angular displacement during a fundamental cycle was significantly larger during scrubbing than during mopping. Results from the inclinometer measurements of back flexion are shown in Fig. 4 giving the percentage of observed working time spent in 10° intervals of forward flexion in relation to the upright position.

There was a significant difference between the two methods with respect to the time spent in a position of extreme back flexion (>65°). Both groups, however, spent 65% of the observed working time with the back flexed more than 20°.

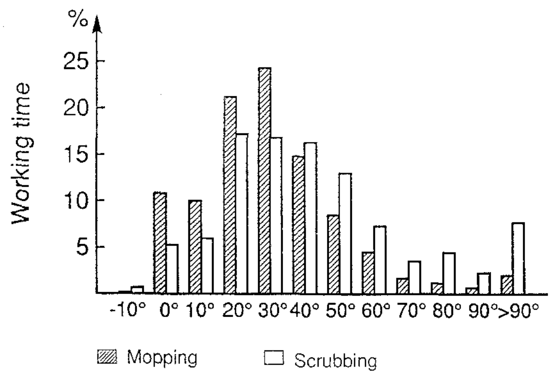

Fig. 4 The percentage of worktime spent in various degrees of forward flexion of the back for the mopping ($n = 6$) and the scrubbing group ($n = 6$). Thje range of each interval is the value given ± 5° i.e. 10° is the range from 5.0° to 14.9°

EMG recordings

The APDF of the myo-electric signal or the relative force of contraction offers a simple profile of the variation in muscle load during a work period, exposing the static level ($P = 0.1$), the median ($P = 0.5$) and the maximum load levels ($P = 0.9$), which estimates the levels at which the muscle activity was below in 10%, 50% and 90% of the recording time, respectively (Jonsson 1978). The APDF calculated from the EMG recordings from the trapezius muscle during floor cleaning showed that for the whole group ($n = 12$) $P = 0.1$ was 10% (range 4%–23%) MVC, $P = 0.5$ was 25% (range 7%–50%) MVC and $P = 0.9$ was 54% (range 17%–96%) MVC. The results for the two methods are shown in Fig. 5. There were no significant differences between working methods, but there was a tendency towards larger values at all levels for the mopping

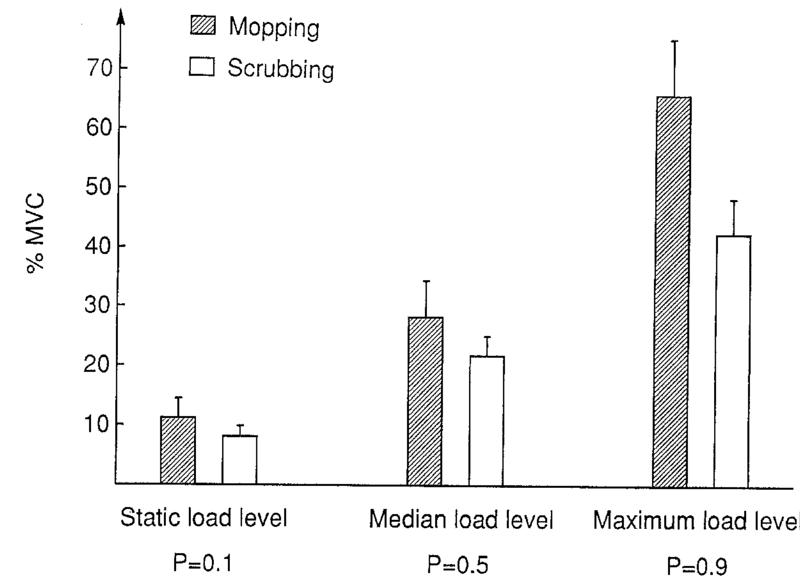

Fig. 5 The static, median and peak level of the electomyogram signal obtained from the trapezius muscle during floor cleaning for the mopping group ($n = 6$) and the scrubbing group ($n = 6$). *Vertical bars* indicate SEM. *%MVC* percentage maximal voluntary contraction

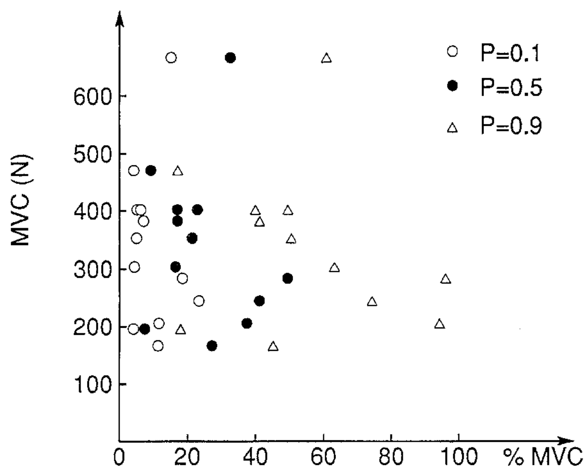

Fig. 6 The static (unfilled dots), median (*filled dots*) and peak (*triangles*) electromyogram levels in the upper trapezius muscle during floor cleaning in relation to the maximal voluntary contraction (*MVC*) of the subject

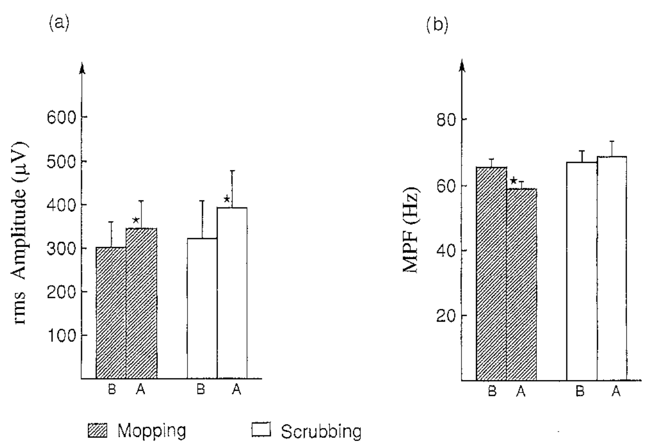

Fig. 7 Results from the analysis of the test contraction performed before **B** and after **A** the work period for the scrubbing group ($n = 6$) and the mopping group ($n = 6$). In (**a**) the root mean square (*rms*) values are shown and in (**b**) the mean power frequency (*MPF*) values. ★ Significant difference between test *A* and test *B*. *Vertical bars* indicate SEM

group. The lack of significance was probably due to the small sample size in combination with the large individual differences indicated by the range of the values. For the 12 subjects, the maximal shoulder elevation strength (MVC) was not significantly related to either the static, the mean, or the peak muscle load during floor cleaning (Fig. 6). Furthermore, no tendency was found towards lower MVC values for the subjects who had reported experiencing shoulder trouble during the last 12 months.

Figure 7 presents MPF and rms-amplitude values from the test contractions. In both groups a significant increase in the rms-amplitude of the EMG signal could be observed when pre and postwork time test results were compared. This was accompanied by a significant decrease in MPF for the mopping group, whereas in the scrubbing group a tendency to an increase in postwork time values was seen in the MPF.

Discussion

Work requiring an absolute oxygen demand just below 1 liter $\dot{V}O_2$ would in general be classified as moderate work (Åstrand 1960). For the group of elderly female cleaners (mean age 52 years) in the present study, however, the work demands corresponded to a relative workload of 53% $\dot{V}O_{2max}$. This level clearly exceeds the 33% $\dot{V}O_{2max}$ suggested by the International Labour Organisation (ILO) as the highest acceptable load during an 8-h working day (Bonjer 1971; Jørgensen 1985; Vanwonterghem 1986). It should be noted that the predicted maximal aerobic power of the study population was within the normal or expected range with respect to age and sex, although at the lower end of the range (Jørgensen 1985).

It is of interest that the absolute $\dot{V}O_2$ during floor cleaning was similar for all the subjects and similar to the estimated values during floor cleaning in earlier studies (Hagner and Hagberg 1989; Louhevaara et al. 1989). This was the case even though the cleaners' work was not machine-paced and there was some possibility of individual choice of posture and movement indicating that the energy cost of floor cleaning is relatively constant and that the maximal capacity of the individual determines the relative load. This was confirmed by a significant and straightforward relationship between the relative $\dot{V}O_2$ and the subject's predicted maximal aerobic power; the higher the capacity the lower the relative load during work (Fig. 3).

Although floor cleaning was not performed during the whole of an 8-h working period, floor cleaning was the main task. During the rest of the time the women performed different tasks such as cleaning sinks and other surfaces like the blackboard, tables and chair, as well as sweeping, tidying up and emptying wastepaper baskets. In general, HR during these activities was lower than during floor cleaning but not to an extent which could lower the average work load to an acceptable level.

Compared to jobs normally classified as physically heavy the relative work load found in this study was remarkably high. As an example, it has been reported that lumberjacks showed a similar load of about 50% $\dot{V}O_{2max}$ during wood cutting (Hagen et al. 1993). However, other studies of cleaners have reported values corresponding to those found in the present study (Hagner and Hagberg 1989; Louhevaara et al. 1989). It is of interest that the high values found in the earlier studies have been ascribed partly to the subjects being unaccustomed to the laboratory conditions and working at an unusually high work pace, and partly to the generally low $\dot{V}O_2$ capacity of the subjects.

In theory it would be possible to lower the relative strain by improving the subjects' individual capacity. However, earlier studies have reported large difficulties and disappointing results when trying to improve training habits and introduce lifestyle changes among middle-aged women (Blair et al. 1988).

Although the subjects in this study were within the normal range for their age group regarding $\dot{V}O_{2max}$, they were at the lower end of the range (Hossack and Bruce 1982; Jørgensen 1985). It might be expected that the long length of service in a job imposing a high degree of physical activity would have resulted in a relatively high $\dot{V}O_{2max}$. Obviously this was not the case in the present study and this is consistent with results from previous studies (Ilmarinen et al. 1991).

Despite the obvious differences in methods, i.e. the incorporation of resting values in the HR method, the relative load based on $\dot{V}O_2$ during work for the mopping group as well as the scrubbing group was quite similar to the relative load based on HR during work. The practical implication would seem to be that during floor cleaning, a reliable estimate of the workload at a group level can be made from the relative HR.

The recordings of work movements and postures exhibited large inter-individual variations. Nevertheless, some common characteristics of the two cleaning methods could be seen. During both mopping and scrubbing the UP-arm was never below 15° of abduction and was lifted and lowered approximately 40° within 2 s. A prerequisite for the performance of these highly repetitive movements is probably a large amount of stabilization in the shoulder joint, thereby imposing a static load on the shoulder muscles. This was confirmed by the high level of static activity in the trapezius muscle, but it may also relate to other shoulder muscles involved in stabilization, e.g. the rotator cuff muscles. In accordance with this, repetitive work with a cycle time of less than 30 s has been found to be a risk factor for develoment of shoulder and neck disorders (Chiang et al. 1993).

Although mean back flexion was similar during mopping and scrubbing, the angular amplitude of movement during a fundamental work cycle was significantly larger for the scrubbing group. This is indicate a relatively constant back flexion during mopping imposing a predominantly static load in the back extensor muscles. During scrubbing the larger variation in back flexion indicated a more dynamic loading of the back, which may be an advantage for the back extensor muscles. In contrast, the large percentage of the working period spent in extreme poitions of more than 65° flexion of the back may have been a disadvantage for the scrubbing group. These differences may, however, be of minor practical importance; cleaners in both groups spent 65% of the time used for floor cleaning more than 20° flexion, which has been considered potentially hazardous with respect to occupational low back pain (Andersson et al. 1981).

The neck joints were not in any extreme positions during floor cleaning (mean values of 14° and 23° flexion for scrubbing and mopping, respectively). However, as a consequence of the high degree of back flexion, the neck flexion in relation to vertical was high and this imposed a substantial load on the neck extensor muscles. Only when the fundamental work cycles were interrupted by washing-out and squeezing the cloth or the mop, were the eyes focused away from the floor with the neck flexion becoming lower than the 15° which has been recommended as a guideline (Andersson et al. 1983). A neck flexion at this level has been taken to indicate that the neck extensor muscles are working at a level of about 15% of their maximal capacity (Hagberg and Hagberg 1989; Moroney et al. 1988).

The static load on the shoulder muscles during floor cleaning was about twice the level of the 2%–5% MVC suggested as a threshold limit value for an 8-h working day (Jonsson 1978). Even this limit is probably too high and numerous studies have indicated that fatigue and disorder can be provoked even at static loads corresponding to 1% MVC (Veiersted et al. 1990). There was no significant difference between the mopping and the scrubbing group regarding muscle loads levels, although a tendency to larger values at all levels was found for the mopping group.

Marked static load levels corresponding to 10% MVC as seen in the present study have been normally found during machine paced and highly repetitive work, e.g. sewing machine operation, or assembly work in the electronics industry (Christensen 1986; Jensen et al. 1993).

In contrast to these studies the cleaners, in addition, had high median and peak load levels (25% MVC and 54% MVC, respectively). However, these high values are similar to the results of a previous study of cleaning (Winkel et al. 1983). When compared to other work tasks, floor cleaning appears to be among the most strenuous for the trapezius muscle [a comprehensive list of studies on this muscle has been presented elsewhere, see Takala (1991)]. It is of interest that similar high levels of median and peak values in the upper trapezius muscle have been found during cleaning of vertical surfaces, which is a task also seen in occupational cleaning (Björkstén et al. 1987). The high relative load on the muscles during cleaning work may be assumed to be a consequence of low MVC for the subjects. However, when compared to other occupational studies of women in the same age group, MVC during shoulder elevation have been in the same range (Christensen 1986).

Large inter-individual differences in work postures as well as relative muscle load during comparable work tasks have been reported (Hagner and Hagberg 1989; Kilbom and Persson 1987; Veiersted et al. 1990). This could be ascribed to differences in individual MVC. However, results from the present study clearly indicated that static as well as median and peak levels of muscle activity were independent of the subjects MVC (Fig. 6). In obvious contrast to the results for circulatory strain no link was found between a high capacity and a low work load with respect to muscle load. A relationship between high muscle strength and low risk for development of disorders has been reported for work tasks characterized by exertion of significant external forces (Kilbom 1988). In contrast, for work tasks characterized by prolonged static postural loads, no effect of high muscle strength in prevention of development of work related shoulder/neck troubles has been found (Kilbom and Persson 1985). Likewise, it has been shown that upper extremity strength capabilities are poor predictors of fatigue and discomfort during repetitive work (Wiker et al. 1990).

As expected from the high values of static load during work, the pre versus postwork test contractions for the mopping group showed the classical EMG signs of fatigue, i.e. a decrease in MPF and a simultaneous increase in rms-amplitude. The scrubbing group also showed the expected increase in rms-amplitude but accompanied by a tendency to an increase in MPF. This difference between the mopping and scrubbing groups may be a consequence of the tendency to higher levels of static activity in the trapezius muscle during mopping. Another striking difference between the two groups was the variation in angular velocity. During a fundamental work cycle, mean velocity was similar but the scrubbing group reached a significantly larger peak velocity than the mopping group, who kept a more constant speed. This may indicate that not only the variation in force but also the velocity of muscle contraction play a role in preventing fatigue development.

Conclusion

Floor cleaning is associated with high cardiovascular and muscle load levels and imposes a large number of improper working postures on the neck, shoulder, and low back. The introduction of the new mopping system cannot be recommended as a general means of reducing work strain during floor cleaning. This conclusion was based on the finding of high and almost identical cardiovascular load levels during scrubbing and mopping. Further, the time spent in extreme forward back flexion was shorter during mopping, but this positive tendency was counteracted by a high static work load and more pronounced signs of fatigue in the trapezius muscle after the working period.

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