Safety and Health at Work 11 (2020) 80–87

Contents lists available at ScienceDirect

Safety and Health at Work

journal homepage: www.e-shaw.net

Original Article

Prevalence of MSDs and Postural Risk Assessment in Floor Mopping Activity Through Subjective and Objective Measures

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ARTICLE INFO

Article history:
Received 11 August 2019
Received in revised form
26 November 2019
Accepted 11 December 2019
Available online 19 December 2019

Keywords:
electromyography
floor mopping
motion analysis
observational ergonomic assessment tool
upper-extremities musculoskeletal disorder

ABSTRACT

Background: Residential and commercial cleaning is a part of our daily routine to maintain sanitation around the environment. Health care of professionals involved in such cleaning activities has become a major concern all over the world. The present study investigates the risk of musculoskeletal disorders in professional cleaners involved in floor mopping tasks.
Methods: A cross-sectional study was performed on 132 mopping professionals using a modified Nordic questionnaire. The Pearson correlation test was implemented to study the association of perceived pain with work experience. The muscle strain and postural risk were evaluated by means of three-channel electromyography and real-time motion capture respectively of 15 professionals during floor mopping.
Results: Regarding musculoskeletal injuries, risk was reported majorly in the right hand, lower back, left wrist, right shoulder, left biceps, and right wrist of the workers. Work experience had a low negative association with MSDs in the left wrist, right wrist, right elbow, lower back, and right lower arm ($p < 0.01$). Surface EMG showed occurrence of higher muscle activity in upper trapezius and biceps brachii (BB) muscles of the dominant hand and flexor carpi radialis and BB muscles of the nondominant hand positioned at the upper and lower portion of the mop rod, respectively.
Conclusion: Ergonomic mediations should be executed to lessen the observed risk of musculoskeletal injuries in this professional group of workers.

1. Introduction

Work associated musculoskeletal injuries/disorders (MSDs) are the most common types of health issues affecting billions of people worldwide [1,2]. Workers employed in various sectors of manufacturing, construction, agriculture, transport, etc and using their bare hands to work with tools, machineries and day-to-day equipment of daily living are often prone to uncomfortable postures, over extensions, forceful exertions, and repetitive movements for a long period. This leads to muscle dysfunction, tingling, inflammation, and pain in their musculoskeletal systems causing serious injuries or disabilities [3–5]. This in-turn increases the absenteeism rate, health care costs, compensation costs, etc affecting organizational growth [6–9]. In personal service sectors, majority of the workers take on cleaning tasks and mostly are unskilled and uneducated women belonging to low economic background [1]. MSDs related to these professions affect around 90% of the population, with the wrist (41.7%), elbow (33%), shoulder (41.1%), and lower back (37.8%) of the workers being most frequently affected [1]. The associated reasons could be the continuous repetitive movements due to awkward postures as observed in most of the cleaning activities (dusting, wiping, mopping, and sweeping) [10].

Floor mopping using a mop stick is a cleaning task considered as a moderately heavy job involving repetitive movements of upper extremities [11]. The task involves asymmetric movement of both the hands. As mentioned by Chang et al [1], the upper hand directs the mop while the lower hand drives it. A systematic review conducted by Kumar and Kumar [12] and Charles et al [13] reveals that cleaning activity is associated with high physical load, mental disorder, societal stigma, and psychosocial stresses. Louhevaara et al [14] investigated variation of cardiorespiratory strain occurring in female cleaners while varying the quantity of water from dry to wet in floor mopping. They reported that oxygen consumption, rate of perceived exertion, and heart rate in dry mopping cause less cardiorespiratory strain than the watery (wet) methods. In the findings of Wallius et al [15,16], wrist angles,

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2093-7911/$ – see front matter
https://doi.org/10.1016/j.shaw.2019.12.005

upper arm elevation and angular velocities during floor mopping were presented along with EMG data of various muscles of hand and upper arms by varying mop handle height to reach different body levels. They suggested that maintaining mop stick height between chin and shoulder level results in lesser muscle activity at the shoulder, lower arm position and neutral arm posture. MSDs of the hand and finger regions increase with change of hand tools, grip effort, repetitive motion, etc as observed by researchers in similar perspectives [17–19]. Merino et al [9] investigated the banana harvesting activity using subjective and objective techniques focusing on real-time motion capture and surface electromyography (EMG). Their study identified ergonomic risks related to extension, flexion, radial and ulnar deviation of wrists, forward and lateral flexion of trunk, and flexion and abduction of shoulders.

Various strategies to evaluate subjective user perceptions and physiological demands toward usage of product/tools have been proposed and discussed in the past studies [12,20–23]. Quantitative measurement of awkward posture, over extension, forceful exertion (heavy lifting), and repetitive movement of body segments are crucial [24]. Many studies have mentioned work pressure, time constraints, and lack of break in working hours as other psychosocial factors (physical stress factor) reducing work efficiency [11]. Using the participatory ergonomics method, Kumar et al [25] suggested that improved work environment reduces number of awkward postures during cleaning. Kinematic variability of upper extremity was recorded using a motion tracking system to determine fatigue in an assembly task [26]. Akhmad and Arendra [27] developed a kinetic model using motion capture instrumentation to assist Rapid Upper Limb Assessment (RULA). Posture analysis using RULA and Rapid Entire Body Assessment (REBA) techniques show that workers adopt postures beyond their secure limit during work in unorganized sectors [8,28,29].

Sogaard et al [30] found that the use of a long handle mop reduces the extreme forward bending of the trunk compared to the traditional scrubbing using a clothing method. An upgradation in the cleaning tool could make use of an adjustable handle [15]. Woods and Buckle [10,31] have suggested adjustable handle height, smooth mop handle surface, rubber coating on top of the mop, and easily squeezable mops for mopping equipment to reduce MSDs in cleaners. They recommended work organizational changes to cleaning managers, designers, supervisors, and manufacturer to reduce musculoskeletal illness.

Specific study on musculoskeletal symptoms, muscle strain with postural risk, and other health issues considering Indian mopping professionals is almost absent. Therefore, the aim of this study is to evaluate the prevalence of musculoskeletal risks inherent in a floor-mopping task among professional cleaners in India. Total of 132 volunteer mopping professionals working in three different organizations shared their job experience, demographic details, and other work/health issues in a questionnaire study. Electromyography activities of three different upper extremity muscles of selected 15 healthy participants were measured during a standardized floor mopping activity to identify the occurrence of muscle strain. Regarding motion/movement analysis, we identified the associated postural risk in a floor mopping activity with a view to implement future ergonomic interventions in equipment/tool design for decreasing the identified physical risk.

2. Methodology

2.1. Questionnaire study

Approximately 88, 15, and 80 mopping workers in the National Institute of Technology (NIT) Rourkela, Community Welfare Society (CWS) Hospital and Ispat General Hospital (IGH) respectively under the cleaner-staffing contractors in Rourkela, India were approached to participate in the questionnaire study. Among them, 62, 12 and 58 cleaners selected randomly from NIT, CWS, IGH respectively completed the study, and 51 either failed to complete the questionnaire or refused to participate. The inclusive criteria were at least 6 months of employment as a cleaner; performing floor mopping as their daily routine. Each subject among 62 participants from NIT Rourkela was asked to participate in the instrumental measurements (EMG and real-time motion capture) during floor mopping in a laboratory set up, and a total of 15 eligible cleaners (3 males and 12 females) agreed (mean age = 33.13 and standard deviation (SD) = 7.080 years). Due to restriction of displacing motion capture instruments at the biomechanics laboratory and ease in availability of the cleaning staff, cleaners of NIT Rourkela were preferred for scientific measurements and motion analysis. For instrumental measurements, healthy participants with no past injuries were eligible. Exclusive criteria included no muscle disorders or severe pain at the time of experiments and no cases of pregnancy.

Socio-demographic data related to gender, age, education level, height, body mass index (BMI), work experience, and dominant hand were collected. Information was gathered related to their occupation, job satisfaction, and general health like working hours per day/week and past injuries. A modified Nordic questionnaire was framed to know the musculoskeletal symptoms of mopping professionals. The pain perception was noted using a Likert scale [19,22] of 1–5 denoting an increasing level of pain intensity; 1 showing no pain to 5 showing extreme pain in different upper body regions like neck, upper and lower back, shoulders, biceps and triceps muscles, elbows, lower arms, wrists, and hands. These defined upper-body regions were visually labeled by means of color-coding for easy understanding of the participants. Prior to the investigation, required permission was taken from the respective organizations and the institute's ethical clearance committee. Participants volunteered and the complete study information was explained in their local language and a signed consent was taken prior to the experimental tasks.

2.2. Mop instrument

The cleaning tasks were performed using a mop having an aluminum alloy handle and replaceable microfiber yarn head (Taara Hygiene Enterprises, India, Roots EZE clean). The height of the mop handle varied from 1 to 1.96 m and had a rubber grip attached at the top end. The height of the mop stick was fixed between chin and shoulder level of the participants as recommended by Wallius et al [15,16] for all the mopping tasks. The mop cloth was moisturized using 70 mL water without any cleaning solution.

2.3. Experiment design

For subjective assessment, prior to filling the questionnaire, participants were asked to mop a highly polished floor surface of dimension $10m \times 2m$. They were encouraged to use their normal rhythm of mopping. The push-mopping technique where the mop pad follows a back and forth linear motion was adopted in the tasks due to the preference of professional cleaners [32]. For the objective assessment, all the experimental tasks were performed in a biomechanics laboratory setup where mopping trials were carried out in a similar polished floor surface of dimension $3m \times 2m$. Groups of 15 healthy participants habituated to the push-mopping technique with no past injuries were selected to assess muscle strain and to perform posture analysis. All the participants had their right hand as the dominant one. During experiments, participants equipped with scientific devices on different body parts practiced mopping for 2 minutes prior to actual data recording so that consciousness of the attached devices is minimum.

2.4. Statistical analysis

The data collected using the questionnaire study was statistically analyzed using IBM SPSS Statistics 24.0. We performed a Pearson's correlation test to reveal the association between work experience and musculoskeletal disorders at different body regions of mopping professionals. The strength of the correlation between these two factors was analyzed for the adopted significance level of $p < 0.05$ [33–35]. The Pearson's correlation coefficient (r) determines the association, either positive or negative having high (strong)/moderate/low (poor)/negligible (very poor) correlation.

2.5. Surface electromyography

The electrical activity produced by skeletal muscles during floor mopping was recorded for all the 15 participants. Surface EMG electrodes were placed on the skin overlying a muscle to detect its physiological characteristics occurring during mopping activity. Six channel EMG sensors (Advancer Technologies EMG sensors V3.0, North Carolina) with a sampling rate of 457 samples per sec were placed on the flexor carpi radiallis (FCR) and biceps brachii (BB) muscles of both the hands and the two upper trapezius (UT) muscles near shoulders. Fig. 1 depicts the electrode placements on respective muscles. FCR and BB are responsible for the movement of wrist and elbow respectively and UT muscles for the movement of shoulder and neck [9,15,19]. The superficial positions of these muscles makes it easy for the placement of EMG electrodes. One Arduino UNO (Adrax, model no. 81037) was used for the collection of electrical activity produced during the tasks. Electrode placements on BB and UT muscles were performed in accordance with the SENIAM guidelines [36] and for FCR, guidelines mentioned by Ghapanchizadeh et al [37] were adopted. To identify FCR muscles, manual muscle test was performed placing the bipolar surface electrodes along the underlying muscle at 20 mm distance from the lateral epicondyle toward the median nerve of wrist and reference electrode at the bony area of the elbow joint. Here, electrodes with a smaller surface area (diameter below 10 mm) reduce bipolar spacing and thus reduce the potential cross-talk effectively. Before placement of electrodes, skin preparation was done to reduce the noise while getting EMG signals. The skin surface was shaved to remove the hair and was cleaned with cotton dipped in alcohol to eliminate any dirt over the skin. Butterworth filter of the 20th order was used to filter high- and low-amplitude noise in MATLAB R2016b. The signal band passes with a cut-off frequency ranging from 10 to 400 Hz. Cyclic RMS was calculated for a window size of 100 samples. For normalization, participants were asked to apply maximum possible resistance in an erect sitting posture for 5 seconds. The activity was repeated for five times to get maximum voluntary contraction (MVC). A break of 5 minutes was provided between each trial to reduce the effect of previous muscle fatigue. Hundred percentage of maximum voluntary contraction (100% MVC) value corresponding to the maximum contraction among all the trials for each muscles was calculated for each candidate.

The experimental task for the measurement of muscle strain in push mopping was conducted for 10 trials of each candidate. For all the mopping tasks conducted in a floor surface of area $3 \times 2m^2$, the amplitude probability distribution function (APDF) values at the 10th, 50th and 90th percentile representing static, median and peak activity levels [15] were evaluated.

2.6. RULA analysis

Rapid upper limb assessment is one of the widely used observational ergonomic assessment tools to analyze the postures adopted by workers in any field-based study [34]. Here, a specific score is assigned to a specific posture specifically in relation to the shoulder, hand, and wrist. A combined RULA score at a particular instant of time while conducting a task is calculated to provide one final risk score associated with the current risk level. Here, implementing RULA helps to identify the workers risk levels associated with upper extremity MSDs during mopping tasks. The dynamic motion of the participants performing floor mopping using the push technique was recorded using four high speed Oqus 5.0 optical motion capture cameras (Qualisys, USA). A total number of 18 passive motion capture reflective markers were placed on different anatomical landmarks of the body such as acromion, lateral elbow, lateral wrist, knuckle, anterior superior iliac spine (ASIS), lateral knee and ankle of both the sides of the body, forehead, C7 vertebra, clavicle, and sternum. Initially, the three-dimensional positional data of all the participants in stature was captured to scale the digital model in OpenSim 4.0 to make it subject-specific. Further,

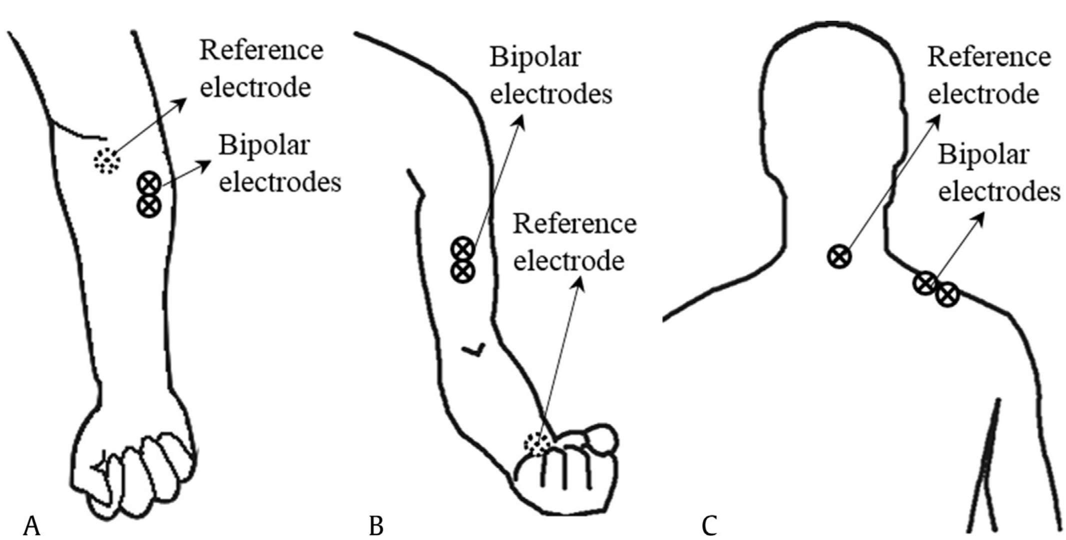

Fig. 1. Placement of bipolar surface electrodes on participant's muscles. (A) Flexor carpi radiallis (FCR). (B) Biceps brachii (BB). (C) Upper trapezius (UT).

Table 1
Demographic details of mopping professionals ($N = 132$)

Variable	Number	Percentage
Gender		
Male	77	58.3
Female	55	41.7
Age group		
20–29	30	22.7
30–39	55	41.7
40–49	39	29.5
50–59	8	6.1
Literacy level		
Illiterate	41	31.1
Primary school	60	45.5
High School	28	21.2
Degree	3	2.3
BMI		
<18.5	13	9.8
18.5–24.9	77	58.3
>25	42	31.8
Work experience		
<1 year	6	4.5
1–5 year	65	49.2
5–10 year	44	33.3
>10 year	17	12.9
Dominant hand		
Left	7	5.3
Right	125	94.7
Health problems		
No problem	72	54.5
Respiratory problem	11	8.3
Gastrointestinal problem	49	37.1
Past injuries in body regions		
Neck	9	6.8
Upper back	13	9.8
Lower back	35	26.5
Shoulder	23	17.4
Bicep muscle	13	9.8
Tricep muscle	9	6.8
Elbow	17	12.9
Lower arms	15	11.4
Wrist	15	11.4
Hand	25	18.9

the individual candidates were asked to perform three trials of mopping and the dynamic motion of attached markers was captured using Qualisys Track Manager with a frequency of 100 frames per second. The dynamic movement was simulated in an OpenSim 4.0 virtual environment while scaling the 3D gait model with simple arms. The individual mopping simulations were observed at a rate of 20 frames per second in order to identify the rapid change in postures. A total of seven prime postures were identified in each cycle of mopping. RULA scores of these seven postures for all the participant's trials were calculated to identify the extreme postures. The maximum RULA score achieved among all the three trials of all the candidates was considered to identify the ergonomic risk level.

3. Results

3.1. Socio-demographic factors and health issues

Table 1 describes the demographic characteristics along with health conditions of the mopping professionals. The age and height of the study group ranged from 20 to 59 years (mean 36.9 and SD 8.2) and 1.42 to 1.78 m (mean 1.61 and SD 8.7) respectively. Among them, 55 were females comprising 41.7% of the study population. Majority of the population (45.5%) had completed their primary school, followed by illiterate (31.1%), high school education (21.2%), and degree level education (2.3%). Around half of the participants (49.2%) selected for the questionnaire study had cleaning experience of 1–5 years. Majority of them used their right hand as the dominant hand (94.7%) which they preferred to position on the upper portion of the mop stick comfortably. The general health reported by them indicated that 37.1% were subjected to gastrointestinal problems. The prevalence of musculoskeletal injuries in various body regions noted during the past 1 year indicated the most affected regions as the lower back (26.5%), shoulder (17.4%) and hand (18.9%) and least being neck and triceps (6.8%).

3.2. Pain ratings

The pain perception levels from no pain to severe pain reported at different upper body regions in mopping professionals during experimental trials are depicted in Fig. 2. The participants reporting higher musculoskeletal complaints in the right hand were 87.1%, lower back (86.4%), left wrist (85.6%), right shoulder (84.1%), left biceps (84.1%), and right wrist (84.1%) and biceps (80.3%) regions. However, least pain was indicated in neck (68.2%) and upper back (68.3%) regions as the task did not involve bending of the neck and lifting any overhead load. The participants body regions perceiving severe pain arranged in decreasing order are right hand (22%) and wrist (17.4%), lower back (16.7%), right shoulder (16.7%), left elbow (15.2%), right elbow (14.4%), left hand (14.4%) and wrist (14.4%), right lower arm (13.9%), triceps (12.9%) and biceps (12.1%), left lower arm (11.4%) and triceps (8.3%), upper back (6%), neck (5.3%), and left shoulder (4.5%).

Fig. 3 illustrates the distribution of mopping professionals with MSDs in various body regions as per their work experience. Participants with a work experience of 1–5 years were found to have high a percentage of pain in the lower back (90.6%), left elbow (90.6%), right triceps (90.6%), right lower arm (90.6%), upper back (89.1%), left lower arm (87.5%), left triceps (85.9%), right elbow (84.4%), left and right biceps (82.8%), neck (78.1%), and left shoulder (78.1%) regions. Similarly, participants having a work experience of 5–10 years were suffering from high MSDs in the right shoulder and hand (93.2%), left hand and wrist (88.6%), and right wrist (86.4%). It is interesting to observe that professionals having a work experience less than 1 year and more than 10 years have lesser prevalence of MSDs-related pain as compared to those in the range of 1–5 and 6–10 years. The least pain was found in the upper back (30%), left tricep and right elbow (40%) for participants having experience less than 1 year and on the left shoulder (41.2%) and left hand (47.1%) for participants having experience more than 10 years.

Table 2 presents the association of work experience with musculoskeletal pains in different body regions. There was a negligible (very poor) significant association between work experience and MSDs in the left shoulder, elbow, hand, biceps, triceps, and lower arm ($r < 0.2$, $p < 0.05$). However, there was a low (poor) negative correlation associated with the left wrist, right wrist, elbow, and lower arm and lower back ($0.2 < r < 0.3$, $p < 0.01$).

3.3. Electromyography analysis

EMG was performed to evaluate the physiological load on the muscles of both the arms involved in floor mopping tasks. EMG parameters as median, mean and standard deviation (SD) values at 10th, 50th, and 90th percentiles of APDF from the UT, BB, and flexor carpi radialis (FCR) muscles expressed in terms of %MVC during

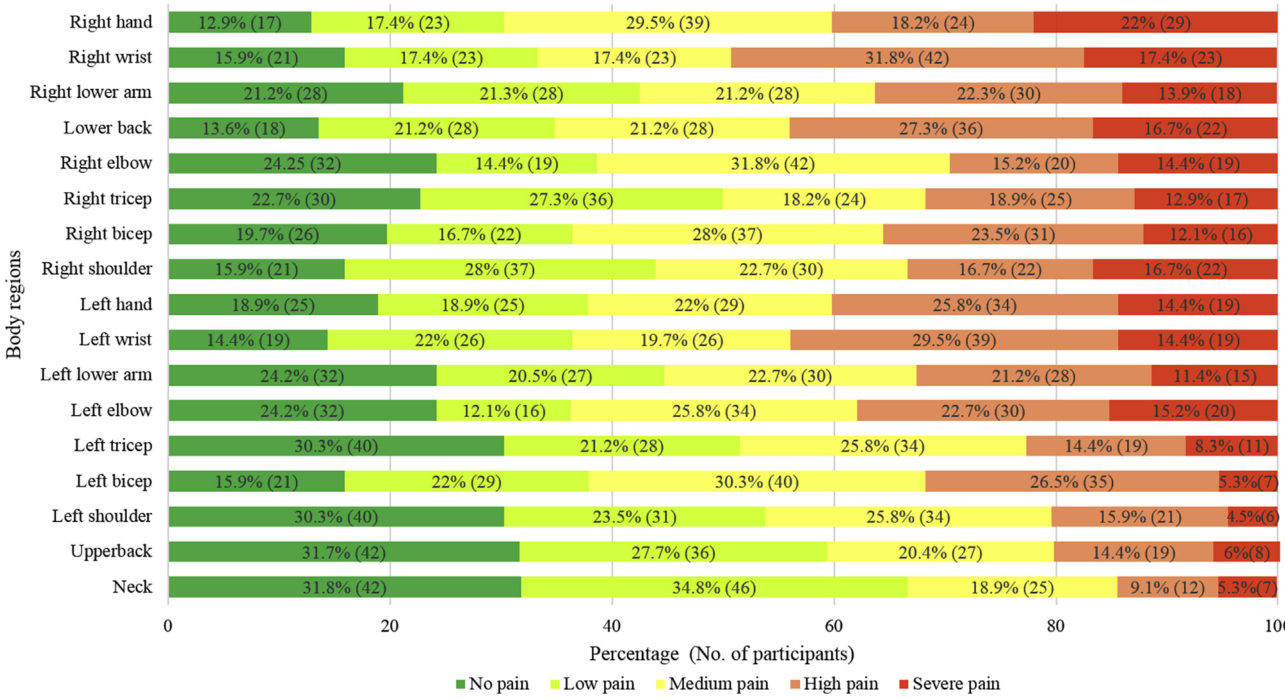

Fig. 2. Pain perception at different upper body regions of mopping professionals.

mopping experiments are shown in Table 3. For APDF10 values signifying static activity level, the mean %MVC ranges from 11.07 to 18.96. The maximum value of %MVC being 18.96 occurs in the BB muscle of the hand placed on the upper part of the mop handle. For APDF50 and APDF90 values denoting median and peak activity levels, the mean %MVC ranged between 17.59 and 28.16 and 22.56 and 38.09 respectively. The maximum values being 28.16 and 38.09 occur in BB and UT muscles respectively of the hand placed on the upper part. For the hand positioned at lower portion of the mop handle, the maximum %MVC value at APDF90 is 33.53 and 32.73 measured for FCR and BB muscles respectively (Table 3).

3.4. RULA analysis

Fig. 4 depicts the seven prime postures observed during the sequential movement of a participant tracing the push-mopping

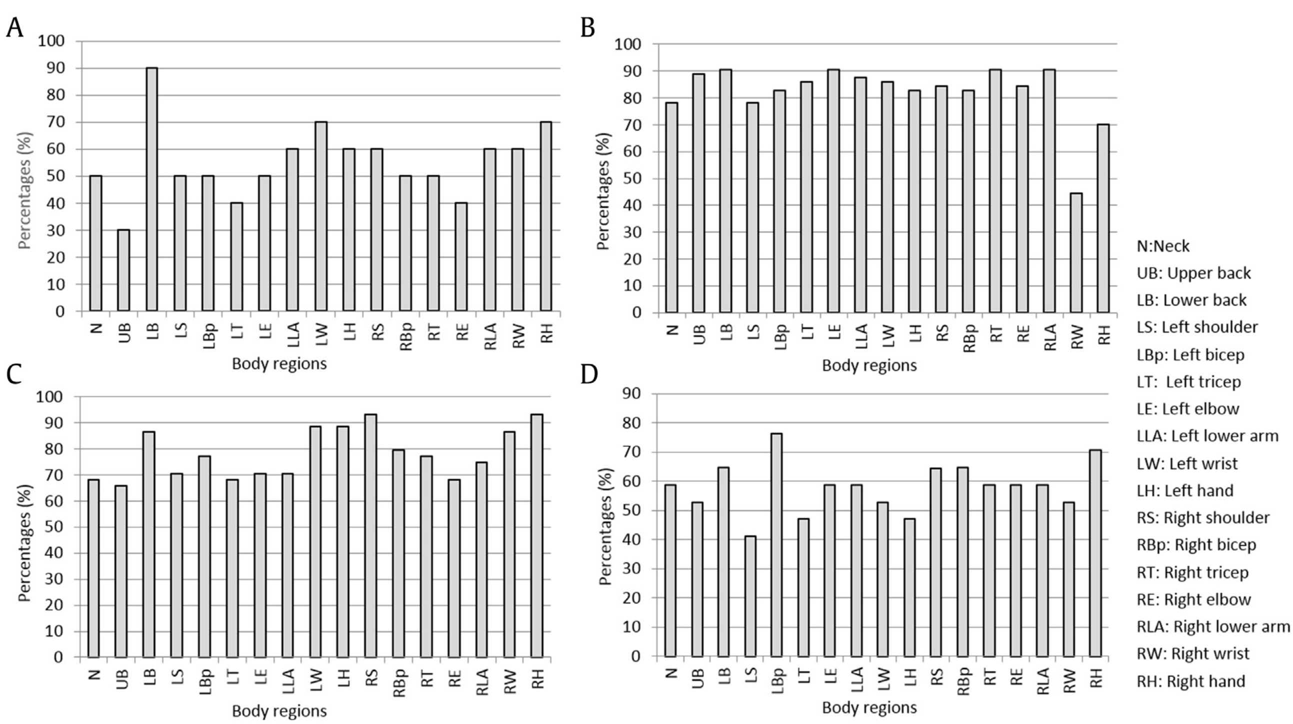

Fig. 3. Prevalence of MSDs revealed by mopping professionals based on work experience. (A) <1 year. (B) 1–5 years. (C) 5–10 years. (D) >10 years.

Table 2
Correlation between work experience and MSDs in various upper body regions

Body regions	Work experience	
	Pearson correlation (r)	Significance value
Neck	−0.065	0.458
Left biceps	−0.176*	0.044
Left triceps	−0.175*	0.045
Left elbow	−0.196*	0.025
Left lower arm	−0.173*	0.048
Left wrist	−0.297**	0.001
Left hand	−0.184*	0.034
Left shoulder	−0.196*	0.024
Right biceps	−0.168	0.054
Right triceps	−0.132	0.132
Right elbow	−0.241**	0.005
Lower back	−0.234**	0.007
Right lower arm	−0.233**	0.007
Right wrist	−0.256**	0.003
Right hand	−0.051	0.565
Upper back	−0.128	0.143
Right shoulder	−0.041	0.637

* Significant at $p < 0.05$.
** significant at $p < 0.01$.

Table 3
Median, mean, and SD values of EMG parameters at APDF10, APDF50, and APDF90 of various muscles in floor mopping tasks

Muscle*	Hand in upper position		Hand in lower position	
	Median	Mean (SD)	Median	Mean (SD)
Upper trapezius				
APDF10	10.67	15.98 (±8.00)	11.42	12.63 (±3.99)
APDF50	23.70	27.04 (±8.66)	15.19	17.59 (±6.23)
APDF90	36.73	38.09 (±12.18)	19.33	22.56 (±9.14)
Biceps brachii				
APDF10	17.27	18.96 (±12.84)	13.63	16.61 (±8.07)
APDF50	25.47	28.16 (±13.01)	20.29	24.67 (±9.86)
APDF90	33.66	37.36 (±13.98)	27.43	32.73 (±12.65)
Flexor carpi radialis				
APDF10	11.16	11.07 (±4.25)	12.82	14.35 (±7.11)
APDF50	15.10	19.56 (±8.67)	21.69	23.94 (±10.95)
APDF90	19.05	28.04 (±14.26)	30.57	33.53 (±16.15)

Note: SD, standard deviation.
* EMG parameters at 10th, 50th, and 90th percentiles of amplitude probability distribution function (APDF) of upper trapezius, biceps brachii, and flexor carpi radialis muscles in %MVC.

trajectory in a single mopping cycle. These postures are associated with the initiation of the mopping with mop stick near to the body, the next two postures denote the forward mopping, the next being the farthest reach of the mop, and the remaining three postures are the motion of the mop stick in the backward direction till it reaches nearest to the body.

Table 4 represents the overall RULA score and postural risk of individual participants calculated during mopping activity. The RULA score for all the 15 participants lies in the range 3−5 having a risk index of 1−1.67 respectively. This corresponds to the risk level from low to medium with majority of the participants (10) showing medium level risk.

4. Discussion

4.1. Pain ratings

Mopping tasks involve high forces and repetitive motions in awkward body postures [10]. Results of the questionnaire study reveal that a significant percentage of mopping professionals reported MSDs in various upper body regions. The most affected parts are right hand, lower back, left wrist, right shoulder, left biceps, right wrist, and right biceps (Fig. 2). Among these, severe pain occurs in right hand, right wrist, lower back, and right shoulder. The push-mopping technique involves movement of the mopping pad linearly in the back and forth direction driving the lumbar/trunk region in repeated flexion−extension motion. The entire task is performed continuously in standing and repetitive bending postures causing overload/stresses in the lower back region. The result corroborates with similar findings involving standing and bending tasks [9,10]. The dominant hand controls the mop steering, positioned at the upper portion of the mop stick [1]. This steering of the mop causes pain in the respective joints/regions due to continuous flexion−extension of the right arm with twisting of the wrist near to the shoulder level. The nondominant hand (the left hand in the present case) drives the mop causing a high expenditure of energy [30] and simultaneous twisting and hyperextension of the wrist joint while propelling the mop, which justifies the pain in the left wrist and biceps regions. This corroborates with the findings of the modified Nordic questionnaire study, which indicates the musculoskeletal injuries mostly in the lower back, hand, wrist, and shoulder with least in the neck based on the last 12 months data related to injuries as shown in Table 1.

The strength of relationship identified using correlation coefficient in the present case between work tenure and pain perception is poor and shows a negative association for most of the body regions (Table 2). A comparatively low negative association is indicated for pain in the left wrist ($p = 0.001$) and right wrist ($p = 0.003$) followed by the right elbow ($p = 0.005$), lower back ($p = 0.007$), and right lower arm ($p = 0.007$). Regarding this behavior, it could be implied that the degree of experience gained in mopping tasks could lead to greater physiological adaptations of professionals which may improve task proficiency. Similar behavior has been corroborated in the past when noting the divergent fatigue behavior of the observed workers during banana-harvesting activity [9]. However, differences can also possibly occur due to small sample of participants having experience less than 1 year and more than 10 years (Table 1) in our case. The reasons for lower participation for experience more than 10 years could be that many might have quit the job due to high MSDs. The information on cleaning professionals quitting the job due to more pain/MSDs symptoms was not available with the cleaner-staffing contractors and is a limitation of the present work. Thus, it is uncertain to access how well the sample corresponds to the study population. Further research is needed while choosing a wider range of parameters in a large sample population to indicate a more reliable result. During interaction, participants also mentioned their job dissatisfaction mostly due to high work pressure. Factors like work pressure, sleep duration and quality, etc could be a plausible cause of higher MSDs and needs future research. Encouragement to the cleaners with increased communication with supervisors is suggested to increase job satisfaction for sustaining good musculoskeletal health.

4.2. Surface EMG

Surface EMG parameters as mentioned in Table 3 clearly indicate remarkable differences in muscle activities of UT, BB, and FCR perceived in both the arms during the experimental trials conducted in the laboratory set up. As mopping requires high repetitive motion with large shoulder movements [13,16], a

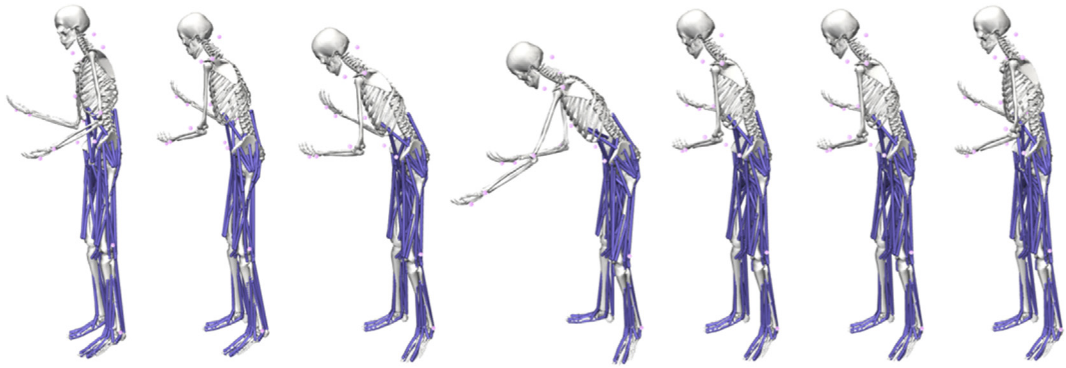

Fig. 4. Sequential postures adopted in a single cycle of the push mopping task.

Table 4
Overall RULA score and risk index of each participants in mopping task

Participant no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RULA score	5	5	5	4	5	5	5	3	5	4	3	5	5	5	4
Risk index	1.67	1.67	1.67	1.33	1.67	1.67	1.67	1	1.67	1.33	1	1.67	1.67	1.67	1.33
Risk level*	M	M	M	L	M	M	M	L	M	L	L	M	M	M	L

* Risk level: M = medium, L = low.

higher muscle activity in UT and BB of the hand in upper portion of the mop stick (right hand in the present case) is justified. The postural simulation performed in the study also verifies that the dominant hand (right) is always maintained at a higher level with repetitive flexion–extension as compared to the non-dominant hand (left) (Fig. 4) leading to higher muscle contraction in right UT. The overhanging of the elbow while steering the mop stick in a continuous fashion tends to increase the muscle activity in the right biceps region. The driving force exerted by the non-dominant hand (left) with simultaneous over extension and twist of the wrist and repeated larger arm bend at the elbow during the mopping task causes higher muscle strain at FCR and BB respectively. Results from a questionnaire study also indicate higher pain in the body regions associated with these muscles. Direct comparison of EMG results with past data may differ due to methodological differences in the electrode placement and the calculation of %MVC. Additionally, the differences could be in the experimental set up, mop equipment/materials, mopping environment, task design and water content in the mop. Additionally, identification of muscle fatigue through EMG measurements with respect to time and frequency domain requires further study. As per our finding, mop handle design needs further investigation to reduce prevalence of high MSDs in wrists and shoulders of mopping professional.

4.3. Postural risk

The results of RULA analysis categorizes the task of floor mopping under medium risk level with a score of five (5). Although the floor mopping activity involves repetitive trunk bending and wrist, arm, and shoulder movements, the activity showed medium risk due to noninvolvement of heavy/overhead load and extreme awkward postures. The middle one among the seven prime postures (Fig. 4) showing extreme lumbar/trunk bending and arm extension being adopted to cover the maximum forward distance of the floor area. Further ergonomic interventions need focus in equipment/tool design modification to have improved posture and the task could be made low risk.

5. Conclusion

This cross-sectional study included 132 mopping professionals in Rourkela, India to evaluate the prevalence of MSDs. Experimental measurements using EMG and optical motion capture systems were performed among 15 cleaners to assess the muscle strain and postural risk involved in floor mopping. Severe (peak) pain occurred in the right hand, wrist and shoulder, and lower back regions. Maximum number of mopping participants observed musculoskeletal injuries frequently in the right hand, shoulder and wrist, lower back, and left wrist and biceps regions. Association of work experience was highly significant with MSDs in most of the body parts showing low negative correlation. Further research on highly experienced cleaners could justify the strength of this association. Surface EMG data showed higher muscle strains in both hands and shoulders indicating high MSDs in floor mopping. Indian mopping professionals need immediate attention and ergonomic design solutions are essential to reduce the observed risks.

Conflicts of interest

The authors declare that no conflict of interest exists with anyone pertaining to this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2019.12.005.

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