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Janitor ergonomics and injuries in the safe workload ergonomic exposure project (SWEEP) study

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ABSTRACT

Introduction: A Minnesota union identified to researchers at the University of Minnesota a concern relevant to a possible relation between their daily workload and outcome of occupational injuries among a population of janitors.
Objective: To assess if the ergonomic workload is related to injuries among janitors.
Methods: Following an initial group discussion among janitors, which identified common and hazardous tasks potentially leading to occupational injuries, a questionnaire was developed, pre-tested, and distributed to the janitors. Questions addressed various exposures, including workload, and comprehensive information regarding injury occurrence over two six-month sequential periods (May 2016–October 2016, November 2016–April 2017). Quantitative ergonomic analyses were performed on a sub-group of janitors (n = 30); these included data collection to identify Borg Perceived Exertion (Borg) and Rapid Entire Body Assessment (REBA) scores. Descriptive, multivariable with bias adjustment analyses were conducted on the resulting data.
Results: Eight tasks were found to be common for janitors. All average REBA scores for the tasks were identified in the high-risk category. The task of repeatedly emptying small trash cans (< 25lb) was significantly related to injuries. Average Borg scores fell between the very light perceived exertion and somewhat difficult perceived exertion categories. Multivariable regression analyses indicated that age-sex-standardized ergonomic workload, measured by task frequencies and REBA or Borg scores, was positively related to injury occurrence.
Conclusions: Standardized ergonomic workload was positively related to injury occurrence. This information serves as a basis for further research and potential intervention efforts.

1. Introduction

Janitors are ubiquitous and understudied (Seixas et al., 2014). In 2016, 2,384,000 people were employed in the field (Janitors and Cleaners, 2018). Their work, involving an apparently high physical workload, appeared to place them at risk for days away from work at a rate 2.7 times higher than all other occupations (Nonfatal, 2016). Reportedly, janitors are exposed to respiratory and dermatologic disorders, psychosocial stressors, mental disorders, infectious diseases, and injuries, particularly involving musculoskeletal disorders (Charles et al., 2009).

Greatly concerned about their workload and potential relation to occupational injury, personnel from the Service Employees International Union Local 26 (SEIU L26) approached researchers in the Division of Environmental Health Sciences at the University of Minnesota to investigate this issue. Their existing measure of workload was, “average square feet cleaned per shift; ” however, the SEIU L26 wanted to consider other workload ascertainment approaches.

In the Seattle area, workload had been studied relevant to perceived intensity, resulting in identification of a positive relation to injuries (Simcox, 2013). School janitors have been studied by examining motions (pushing, pulling, grasping with the left hand, grasping with the right hand etc.), and demonstrating that musculoskeletal injuries were associated with increasing time spent pushing and pulling (Koehoorn et al., 2011). Similar to other service professions, the vast majority of reported janitors’ injuries have involved sprains, strains, and tears, with

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an incidence rate 2.7 times higher for musculoskeletal disorders than the United States (US) occupational average for private industry, state government, and local government (Bureau of Labor Statistics (BLS), 2014). This is an important indication that physical workload needs to be examined in janitors to understand the risk of work-related injuries. Other research in different occupations has found relations between physical workload, ergonomics, and injury (Krause et al., 2004; Dennis et al., 2004); but no apparent in-depth research has been conducted with janitors involving an ergonomics approach.

Therefore, the objective of this study was to conduct an ergonomic workload assessment of routine tasks in the population of SEIU L26 member janitors, and to examine its association with the outcome of occupational injury.

2. Methods

2.1. Study population

Following approval by the University of Minnesota Institutional Review Board, a closed prospective cohort study design was initiated. The sample was drawn from a target population of approximately 4000 janitors who are members of SEIU. Local 26 membership is comprised of approximately 20% Somali, 60% Hispanic, and 20% other ethnicities. This study was done on approximately 1200 janitors who reported that they worked full-time: part-time workers were not used due to higher turnover.

Janitors are reportedly a challenging population to research for several reasons, including turnover, immigrant status, and known lack of reporting of injuries (Greenhouse, 2005). Turnover, defined as an individual's decision to stay or leave a job, is based on the investments that organizations commit to their employees (Hausknecht, 2014). Compared to other occupational groups, janitors generally have high turnover rates (Ohlin and West, 1993). Organizations provide fewer resources for janitors' well-being knowing that there is a chance that their employment may be time-limited for various reasons (Holtom et al., 2008). High turnover in this population is a study limitation, because if the janitors are not consistently working in the same position, they may not be available for follow-up over an extended study period.

The janitorial industry employs many immigrants due to few barriers to entry (Greenhouse, 2005); however, immigrants tend to work in riskier occupations and get injured more often (Orrenius and Zavodny, 2009). Some of these immigrants may be undocumented and, as such, fear reporting unsafe work conditions due to the potential for being deported.

Injuries at work are significantly associated with lower English proficiency (Panikkar et al., 2013); deficiency in both written and spoken English also increases the difficulty of conducting research in this population. Thus, the current research project incorporated English, Spanish, and Somali language translations to enhance participation.

2.2. Selection of tasks to be studied

A group of 30 janitors was formed. A structured questionnaire that addressed the topic of janitorial tasks was developed and administered to this group. Participants were asked to identify the routinely performed tasks that they felt were of greatest concern.

2.3. Questionnaires

Questionnaires regarding work-related injuries were developed by the research team, incorporating the tasks identified during the group session described in section 2.2. A small working group of 19 janitors pre-tested the questionnaires to ensure that wording and concepts were readily understandable; the questionnaires were revised by the research team as appropriate. Some of the working group of 19 also participated in the larger group of 30 janitors that identified priority tasks.

The revised questionnaires were administered to collect occupational injury outcomes and exposure data for two six-month recall periods in a one-year longitudinal study (May 1, 2016–October 31, 2016 and November 1, 2016–April 30, 2017). Work-related injuries were defined as any injuries occurring in the working environment; they resulted from acute traumatic events that involved any of the following: restriction of normal activities for at least 4 h, professional medical care, loss of consciousness, loss of awareness, or amnesia for any length of time. (Gerberich et al., 2001; Erkal et al., 2008). Due to space limitations on the printed questionnaires, a maximum of four detailed descriptions of injury events were collected for each of the two sequential six-month retrospective recall periods for each participant. Approximately 1200 questionnaires were initially distributed to the entire population of full-time SEIU L26 janitors by union stewards at their workplaces. Questionnaire items included demographic information, task exposures, frequency of exposure to musculoskeletal stressors, and occupational injury outcomes. Queries pertinent to injury occurrences included: how many times in the past six months had they been injured, and information on associated consequences.

Lifetime previous injury history was also ascertained via the questionnaire, as there is evidence it is a risk factor for future injury (Hägglund et al., 2006; Meeuwisse et al., 2003). Task-specific information was collected for the following job titles (based on predominantly performed tasks): Floor Cleaner, Bathroom Cleaner, and Special Projects (everything else), as established from the initial group discussions. It was determined that a questionnaire with an average reading grade level of 6.4 and a Flesch-Kincaid Grade Level of 5.7 was appropriate for the study population (io, 2018).

This questionnaire for the janitors included items asking task frequency per shift for each task. For example, janitors were asked the number of large trash cans they emptied in an average shift.

2.4. Janitorial tasks

Eight tasks were identified from the SEIU L26 janitor group, as a result of the participant information collected in the initial focus group, “What are the most frequent tasks? What do you believe are the most dangerous tasks? What are the most difficult tasks?” These questions were open-ended, with each participant being asked to list up to five tasks for each question. The final number of eight was not decided *a priori*; tasks were chosen based on having at least 15 janitors indicate that those tasks were noteworthy.

The eight tasks were: emptying trash cans of less than 25 pounds; emptying trash cans of more than 25 pounds; mopping/sweeping; vacuuming; dusting; cleaning mirrors; cleaning sinks; and cleaning toilets. These were similar to the University of California Custodial Study which studied the tasks of trash and recycled material handling, mopping, vacuuming, lifting and moving furniture, and cleaning bathrooms (Lynch, 2011). Each of the eight tasks has been reported in the literature to include physical exposures that are risk factors for injury such as neck extension, wrist abduction, trunk bending, raising upper extremities above shoulder level, heavy lifting, spinal torque, and others (Keyserling et al., 1992; Buchholz et al., 1996; Nguyen et al., 2001; O'Sullivan et al., 2012; Hansson et al., 1996; Chao et al., 2000; Godwin et al., 2009; Kaminskas, 2001). The janitors indicated that a small trash can typically weighed under 25 pounds.

Due to the inability to observe the tasks, *in situ*, simulations of the eight tasks were created in multiple rooms/areas, comparable to their work settings, and janitors were observed as they cleaned. The janitors were asked to complete the tasks as they typically would.

Research with simulations is only realistic if the simulations are as similar as possible to those encountered in the workplace. For example, if one of the tasks is emptying a trash can of less than 25 pounds, it is not sufficient to place a trash can in the middle of the floor to be

emptied. Instead, the trash can should be in a representative environment – for example, under a desk with an office chair obstructing movement, so that there are realistic obstructions and complications involved in the necessary movement. Ergonomists, union officials, and experienced janitors contributed input for the simulations; then, stations were created to simulate all eight tasks.

The eight tasks are described below:

1. Emptying large trash cans: Janitors were asked to move two preloaded 40-pound trash cans on rolling platforms for 20 feet, and then empty the cans, after which they were to place new bags in the cans.
2. Emptying small (less than 25 pounds) trash cans: There were four 15-pound trash cans; janitors were asked to grab them from under the desks, tie off and empty the bags, put new liners in the cans, put the small bags into a large (over 25 lbs) bin, and then replace the small bins under the desks.
3. Mopping: A 10 foot × 10 foot polished concrete floor was marked off with yellow tape. Inside the area was a table and three folding chairs. Janitors were given a Kentucky string mop and mop bucket with wringer and asked to clean the floor. Janitors either moved the chairs onto the table, out of the 10 foot x10 foot area, or simply mopped around the furniture.
4. Vacuuming: Two 3 foot × 8 foot coarse rugs were placed side by side, creating a 6 foot × 8 foot area. Janitors were asked to plug in a standing-style vacuum cleaner to an extension cord, vacuum the rugs and, then, unplug the vacuum cord.
5. Dusting: In an office cubical, purple duct tape was placed on several surfaces to provide standardized cleaning areas. The horizontal surfaces were the: top of the cubical walls; top of the monitor and computer tower; and a filing cabinet. Vertical surfaces included a telephone, part of a desk lamp, and several pictures on the wall. Janitors were provided a feather duster for this activity.
6. Cleaning toilets: Janitors were asked to wipe down the toilet outer surface with a cloth, scrub the bowl with a long-handled brush, and refill the toilet paper dispenser.
7. Mirrors: Janitors were asked to clean a mirror that was 2 × 3 feet. They were given a cloth and a spray bottle that weighed five pounds to accomplish this.
8. Sinks: Janitors were asked to clean a white porcelain sink mounted in a cabinet that was 2.5 feet wide, 2 feet deep, and 3 feet tall. To do this, they were given a cloth and a spray bottle that weighed five pounds.

2.5. Ergonomic assessment of tasks

This study operationally defined ergonomic workload as a construct comprised of Rapid Entire Body Assessment (REBA) scores, Borg scale scores, and frequency of task performance. REBA is a practitioner's field tool (Coyle, 2005; Motamedzade et al., 2011), designed to assess postures, forceful exertions, type of movement or action, repetition, and coupling. It is "sensitive to musculoskeletal risks in a variety of tasks, divides the body into segments to be coded individually with reference to movement planes, and provides a scoring system for muscle activity caused by static, dynamic, rapidly changing or unstable postures." (32) REBA is commonly implemented in the world of ergonomics research as well as its use as a tool for ergonomists operating in industry (Janowitz et al., 2006; Jones and Kumar, 2010; Kee and Karwowski, 2007; Pascual and Naqvi, 2008; Nawi and Nordin, 2013). This scale was created by a group of ergonomists, physical and occupational therapists, and nurses who divided the body into segments and coded over 600 different postures commonly found in the health, manufacturing, and electricity industries (Hignett and McAtamney, 2000). It has been shown to be generally consistent with the New Zealand Manual Handling Hazard Control Record, the Rapid Upper Limb Assessment, the Manual Task Risk Assessment Tool, and the National Institute of Occupational Safety and Health (NIOSH) lifting equation (Coyle, 2005; Window, 2006; Gentzler and Stader, 2010). REBA is also being used in the promising domain of virtual reality in occupational safety (Pontonnier et al., 2013). In general, "observation-based assessments [such as the REBA] appear to provide the levels of costs, capacity, versatility, generality and exactness best matched to the needs of occupational safety and health practitioners. Who have limited time and resources at their disposal and need a basis for establishing priorities for intervention." (David, 2005).

The Borg scale enables calculation of a psychophysical basis of perceived exertion (Borg, 1982; Konz and Johnson, 2004). It ranges from 6 (very, very light) to 20 (very, very hard), with data obtained from observer-asked subject self-report. Aside from its use in ergonomics (Shen and Parsons, 1997; Spielholz, 2006; Jakobsen et al., 2014; Kee and Lee, 2012), the Borg scale is used in medicine for various health outcomes, including respiratory disorders (Kendrick et al., 2000; Ries, 2005), perceptual psychology, and exercise science (Kankaanpaa et al., 1997; Ward and Bar-Or, 1990; Wos et al., 1988). The scale has been validated for load weight and physical work capacity (Jackson et al., 1997).

The REBA portion of ergonomic workload was determined in real-time by observing thirty people, 15 men and 15 women. Each of these 30 participants was asked to rate the task performed using the Borg scale. Balanced, (10 in each age group), tertile cut points of the sample were made with groups of ages 21–39, 40–56, and 57–71. The average height for women was 1.59 m and their average weight was 72.6 kg. On average, men were 1.68 m tall and weighed 80.9 kg.

During the simulations, a team of ergonomists independently assessed each person as they performed each of the simulated tasks using REBA and asked the janitor to rate the job on a Borg scale. After categorizing the levels of risk exposure for REBA as negligible, low risk, medium risk, high risk and very high risk, a Fleiss' Kappa of 0.54 was identified, indicating moderate inter-rater reliability. (Landis, Koch., 1977) Multiple snapshot measurements were taken for each task and then combined to obtain a task-specific score. Task-specific scores were then used with the individual task frequencies reported on the survey to obtain a task-summed total ergonomic workload measurement for the targeted janitors.

2.6. Potential confounders

Potentially confounding variables were identified, *a priori*, based on peer-reviewed literature and expert knowledge, through the application of Directed Acyclic Graphs (DAGs). DAGs are a valuable tool used to represent the causal direction of the association between sets of variables and can be used to identify potential confounding variables while excluding extraneous variables that may increase confounding. For each specific research question, the DAGs' pathways were reduced to the smallest logical set of potential confounders to create the simplest, most minimal set of variables to include in the appropriate regression equations between exposures and outcomes. (Hernan et al., 2002; Textor et al., 2011).

The potential confounders included: resting heart rate; (Kristal-Boneh et al., 2000; Goldstein et al., 1998); body mass index (BMI) (Pope et al., 2000; Tyler et al., 2006; Knapik et al., 1993; Twitchett et al., 2010; Krause and Fisher, 1998); injury history (Hägglund et al., 2006; Meeuwisse et al., 2003; Tyler et al., 2006); years worked as a janitor (Krause and Fisher, 1998); years worked for the company (Krause and Fisher, 1998); personal protective equipment use (Robertson, 2007); having a second job (Krause and Fisher, 1998); age (Robertson, 2007); SES (Potter et al., 2005); gender (Potter et al., 2005); United States (U.S.)-born (Salminen et al., 2009); smoking (Reynolds et al., 1994); race (Ellis and Trent, 2001); and marital status (Coombs, 1991). While there is limited literature on the relation between variables such as number of household members, size of company, level of education, and floor/bathroom/special projects cleaners,

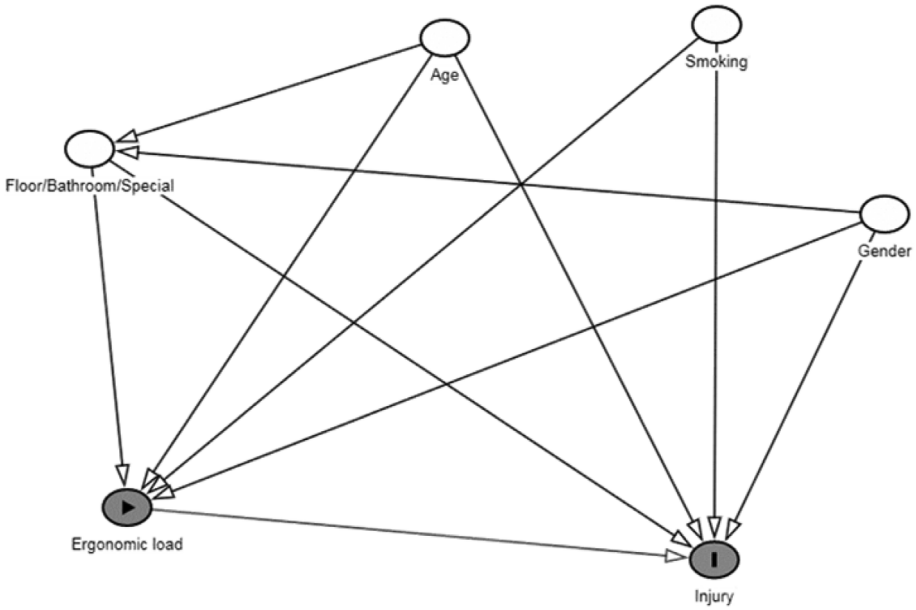

Fig. 1. Directed acyclic graph of the relation between ergonomic workload and injury among janitors.

and the outcome of injury, research team experts also considered their value as potential confounders.

It was hypothesized that an increased *ergonomic workload increases the risk of injury*. To analyze the relation between ergonomic workload and injury, variables of age, gender, smoking, and job title were adjusted, as shown in the DAG in Fig. 1.

2.7. Data management and analysis

Upon survey completion, data were entered by two research team members into a RedCap database and compared for consistency (Harris et al., 2009). Data were cleaned, potential missing variables and outliers were identified, and data were structured for statistical analyses. Injuries reported as occurring outside the study period were excluded from analysis.

The questionnaire results regarding task frequency data were sometimes unclear. In those cases (2% of surveys), where a janitor did not give a numeric answer to a frequency item but, rather, indicated that they did a task (writing an "x", checkmark, or "yes"), the response was imputed to the average value of all janitors who provided a numeric value for that task. Potential outlier responses (a janitor reporting emptying 3000 small trash cans in an 8 h shift, which would be 6.25/minute, presuming no breaks or travel time) were truncated to industry standard production rates, based on an 8-h work shift (which was supported from the questionnaire) (International Sanitary Supply Association I, 2014). No task had a truncation frequency greater than 4 percent.

A task cycle is defined as the time it takes to complete a task, based on standardized intervals provided by the International Sanitary Supply Association (ISSA). Task cycle times were computed for the non-discrete tasks (mopping, vacuuming, dusting) (International Sanitary Supply Association I, 2014). These three time-based variables were standardized to industry-standard work cycles as defined by ISSA when the same tools were used in order to have a counting measure equivalent to the frequency-based variables. For example, if janitors reported mopping for 2 h per shift, the number of cycles per shift was determined by dividing 2 h by the amount of time (e.g., 6 min) that ISSA reported should be required to mop the area of the simulated task – or 20 cycles in this example case. Remainder fractions of a shift were considered to be "partial" task cycles.

Descriptive univariate analyses were conducted to calculate the frequencies and distributions of job tasks and workload measurements. Risk of injury occurrence was assessed for different levels of workload exposures.

The workload exposures were analyzed through log binomial regression models to calculate risk ratios that identify associations with occupational injury occurrences. Generalized Estimating Equations (GEE) were used to account for correlated data for a portion of the analysis. If a single janitor completed the two sequential six-month surveys, GEE was used to avoid clustering bias (Hanley et al., 2003).

$$\ln(\text{Injury Rate}) = \beta_0 + \beta_1 * \text{Ergonomic Workload Tasks} + \beta_2 * \text{Age} + \beta_3 * \text{Gender} + \beta_4 * \text{Smoking} + \beta_5 * \text{Job Title} + \varepsilon$$

Injury Rate = injury incidence per person, β_0 = intercept, $\beta_{1\text{-}4}$ = $\beta_{\text{coefficient for each exposure variable}}$, and ε = error term.

Potential response bias, resulting from a lower response rate, was minimized by inversely weighting observed responses by probabilities of response, estimated as a function of worker characteristics available from the SEIU L26 (Gerberich et al., 2004; Wei et al., 2013). Those characteristics included gender, age, and janitorial contracting company. This technique used re-weighting of estimates using group response characteristics to account for the potential differences in responses (Horvitz and Thompson, 1952).

3. Results

3.1. Survey questionnaire and janitorial assessment data

As shown in Fig. 2, there was an overall survey response rate of 32.5%, with 390 janitors responding to at least one of the two sequential questionnaires; 137 janitors responded to both. Of the 390 janitors who responded, 55% were female. Among the janitors, 10% were aged 18–30 years, 30% were 31–40, 30% were 41–50, 23% were aged 51–60, and 6% were over 60 years. According to reported race, 57% were black or African American, 30% were white, and 13% identified as another race.

For the specific janitorial assessment, each task initiated by a janitor was assessed by ergonomists between 72 and 110 times, with at least 23 janitors measured per task (Table 1). With reference to the REBA scoring key in Table 2, all average REBA scores, based on task-specific assessments, and identified in Table 3, were in the high-risk category.

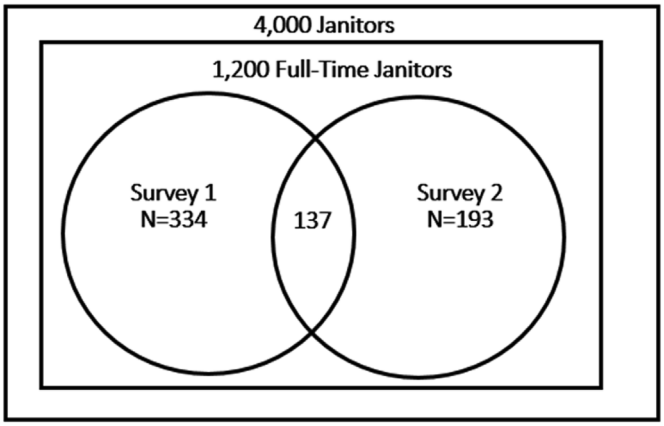

Fig. 2. Study size flow chart for the SWEEP study.

Table 1
Task-specific assessment data: The SWEEP study.

Tasks	# Assessments	# Janitors Assessed	Range of Assessments/ person
Toilet Cleaning	77	25	1–4
Dusting	110	26	1–11
Large Trash	91	23	1–9
Small Trash	99	25	1–12
Mopping	89	24	1–8
Mirror Cleaning	82	26	1–8
Sink Cleaning	72	25	1–4
Vacuuming	98	25	1–10

Using the Borg scoring key, average Borg scores ranged between the very light and somewhat difficult categories (Table 3).

The average REBA and Borg scores are found in Table 3. From the questionnaire data, completed by the janitors, the highest number of task cycles, of a task performed, was mopping, with an average of 56.77 cycles a shift (Table 4). Only 249 responses reported cleaning toilets, with an average of 31.86 cleaned per shift.

Table 4, shown below, does not include those with zero minutes for a task.

From the total of 527 questionnaires completed, there were 78 reported injury events over the 12-month data collection period. Repetitive motion (21%) and overexertion (19%) were the main sources of injuries.

Using data obtained from the questionnaires, bivariate log binomial regressions were performed to examine relations between the exposures of task frequencies and injury outcome. Multivariable regression models were adjusted by gender, age, and smoking status. As shown in Table 5, the only statistically significant results were identified for the small trash category, with a 3% increase in risk of injury for every 10 small trash cans cleaned.

Through further analyses, the task-specific REBA and Borg scores from the quantitative ergonomic assessments were then adjusted to the total participants by combining the individual task frequencies, identified by the janitors in responses on the questionnaires, with the REBA

Table 3
Mean (SD) Ergonomic Impact, based on REBA and Borg Scores, by Task: The SWEEP Study.

Tasks	REBA (SD)	Borg (SD)
Toilet Cleaning	10.4 (2.11)	8.84 (4.27)
Dusting	8.92 (2.41)	5.45 (4.18)
Large Trash	10.49 (1.09)	8.04 (4.92)
Small Trash	10.68 (1.44)	6.22 (4.35)
Mopping	9.13 (1.86)	8.37 (4.49)
Mirror Cleaning	9.27 (1.68)	6.14 (4.51)
Sink Cleaning	8.96 (2.36)	6.76 (4.20)
Vacuuming	9.65 (2.08)	7.13 (4.40)

SD = Standard Deviation.

Table 4
Survey-based task cycle frequency means per shift: The SWEEP study.

Tasks	N	Number of Tasks Cycles per Shift			
		Mean	SD	Minimum	Maximum
Mopping	452	56.77	51.61	0.59	288.69
Vacuuming	424	42.12	27.02	0.35	178.32
Dusting	432	27.91	24.96	0.34	182.29
Toilet Cleaning	249	31.86	34.56	1	170.00
Mirror Cleaning	271	17.04	21.24	1	240.00
Small Trash	329	85.01	102.72	1	320.00
Large Trash	364	19.46	27.24	1	120.00
Sink Cleaning	306	17.58	20.69	1	120.00

SD = Standard Deviation.

Table 5
Multivariable regression analyses of survey-based task frequency exposures and the outcome of injuries: The SWEEP study.

Tasks	Unadjusted Analyses			Adjusted Analyses[b]		
	RR	95% CI	P. Value	RR	CI	P. Value
Mopping	1.02	0.99, 1.06	0.2329	1.02	0.99, 1.06	0.1990
Vacuuming	1.06	0.99, 1.13	0.1028	1.05	0.98, 1.12	0.1954
Dusting	0.99	0.91, 1.09	0.8556	0.98	0.89, 1.09	0.7660
Toilet Cleaning	1.06	0.99, 1.13	0.1077	1.03	0.96, 1.11	0.4636
Mirror Cleaning	1.01	0.91, 1.13	0.7998	1.00	0.89, 1.12	0.9936
Small Trash[a]	**1.03**	**1.01, 1.05**	**0.0117**	**1.03**	**1.01, 1.05**	**0.0118**
Large Trash	0.95	0.86, 1.06	0.3627	0.96	0.87, 1.05	0.3528
Sink Cleaning	1.08	0.99, 1.19	0.0948	1.08	0.99, 1.18	0.0930

RR = Risk Ratio per 10 task cycles.
CI = Confidence Interval.
[a] Significant at 0.05 level.
[b] Adjusted by gender, smoking, and age.

Table 6
Mean ergonomic impact per shift: The SWEEP study.

Measures	N	Mean	SD	Minimum	Maximum
REBA	500	2122.40	1434.30	12.18	8167.83
Borg	500	1548.29	988.40	9.97	5879.17
Standardized REBA	448	2131.25	1433.75	20.23	8019.00
Standardized Borg	448	1616.24	1227.92	16.09	8086.17

SD = Standard Deviation.

Table 2
REBA and borg scoring keys.

REBA Score	REBA Level of Injury Risk	Borg Score	Borg Measure of Intensity
1	Negligible risk, no action required	1–3	Extremely light
2–3	Low risk, change may be needed	4–7	Very light
4–7	Medium risk, further investigation, change soon	8–11	Somewhat difficult
8–10	High risk, investigate and implement change	12–15	Extremely difficult
11 +	Very high risk, implement change		

Table 7
Log binomial regression analyses of the relations between ergonomic workload and injury occurrence: The SWEEP study.

Measures	Unadjusted Analyses				Adjusted Analyses[b]			
	RR	95% CI		P.Value	RR	95% CI		P.Value
REBA[a]	1.10	0.95	1.27	0.2058	1.12	0.97	1.29	0.1138
Borg[a]	1.16	0.94	1.43	0.1677	1.20	0.98	1.48	0.0747
Stand. REBA[a]	1.14	0.98	1.34	0.0944	**1.20**	**1.04**	**1.38**	**0.0123**
Stand. Borg[a]	**1.24**	**1.07**	**1.45**	**0.0061**	**1.25**	**1.06**	**1.47**	**0.0071**

RR = Risk Ratio per 1000 units of the ergonomic workload measure
CI = Confidence Interval.
**Standardized Ergonomic Values were adjusted by smoking and job title.
[a] Significant at 0.05 level.
[b] Ergonomic Values were adjusted by gender, smoking, age, and job title.

and Borg ergonomic assessment scores (Table 6). The final REBA and Borg workload scores were calculated as a sum of the products of the task-specific ergonomic scores and numbers of cycles across all tasks that a janitor performed. These ergonomic exposure scores were standardized by age and gender. The final ergonomic measures, REBA combined with task frequency, and Borg combined with task frequency, were tested for correlation, resulting in a Pearson Correlation Coefficient of 0.89. Correlation between REBA- and Borg-based ergonomic workload measures was statistically significant for each task, ranging from r = 0.74 for vacuuming to r = 0.96 for sink cleaning.

As shown in Table 7, data relevant to the relations between the combined ergonomic measures and injury occurrence were identified for both the unadjusted and adjusted analyses. All of the standardized ergonomic workload measures were statistically significantly associated with the outcome of injury occurrence. The Borg score had the largest point estimate.

4. Discussion

A key finding of this study was that the average REBA scores for all janitorial tasks were identified in the high-risk category. That not a single one of the eight tasks was identified at even a medium risk level for injury is somewhat surprising and concerning (Hignett and McAtamney, 2000). As identified, average Borg scores by task fell between the very light and somewhat difficult categories. Overall findings suggest that janitorial work is difficult; equipment design and manner of task implementation should be rigorously evaluated for potential redesign (Bureau of Labor Statistics (BLS), 2014).

However, similar to the findings in this current study of janitors, other researchers also used REBA scores to identify high-risk job activities. Nawi et al. (Nawi and Nordin, 2013), assessed Malaysian palm oil harvesters and found that all seven tasks had REBA scores that ranged from high risk to very high risk (Nawi and Nordin, 2013). Ansari et al. (Ansari and Sheikh, 2017), reported that 53% of studied Indian factory workers were working at high REBA risk levels, with 33% working at medium risk levels (Ansari and Sheikh, 2017). Gentzler (Gentzler and Stader, 2010) used the REBA (among other techniques) to study firefighters and Emergency Medical Technician personnel, finding extreme risk for some of the similar postures (lifting and reaching) that janitors utilize (Gentzler and Stader, 2010). In Denmark, Jakobsen et al. (2014), compared the Borg scale to muscular load in manual laborers, finding that many blue-collar workers reported a moderate exertion level. Janowitz (33). Used the REBA to study hospital workers in a wide range of positions; support staffers had higher REBA values than administrators or nurses (Janowitz et al., 2006).

Both the REBA and Borg scales are important and useful for ergonomic and injury epidemiology study analyses (Hignett and McAtamney, 2000; Nawi and Nordin, 2013; Spielholz, 2006; Jakobsen et al., 2014; Kendrick et al., 2000; Ries, 2005; Ansari and Sheikh, 2017). However, it has not been common for both scores to be applied in the same study (Jones and Kumar, 2010; Shanahan et al., 2013; Cancela et al., 2014; Chang et al., 2007).

This study found that the overall REBA and Borg scores, when they are combined with task frequencies, are highly correlated (r = 0.89), which is a valuable contribution. The log-binomial regression analysis presented in Table 7 demonstrates that both the adjusted REBA and Borg scales were significant predictors of injury. Because the Borg scale is a single-item score and does not require training for its use, it appears that it may offer some potential advantage as a screening tool that might best be used before more advanced tools, such as the REBA (Baron et al., 1996). Similar to this current SWEEP Study finding, Kee and Lee (2012) found that the Borg is an easier method to use in risk assessment than objective tools that measure variables such as "the angular deviation of a body from a neutral position". They also noted that the Borg and other tools, such as REBA, allow assessment without disrupting the workers (Kee and Lee, 2012).

Individual task frequencies were studied for their relations to injuries. All of the data (janitorial task frequencies for an average shift and injury outcomes) came from the self-reported questionnaires. Braun and Gerberich et al. (Braun et al., 1994), found that self-reported data tend to have injury prevalence underreported. None of the current SWEEP questionnaire data indicated a relation to injuries (with the notable exception of the small trash can task). Questionnaires (paper, web-based, and interviews) are often one of the main methods used for data collection by epidemiologists (van Gelder et al., 2010), so a strength of this study was the addition of quantifiable ergonomic techniques that enabled identification of more specific results relevant to ergonomic load.

There were increased risks identified in the analyses of the relations between all standardized ergonomic scores and injury outcome. However, there was not a demonstrated risk for the non-standardized ergonomic scores. This indicates the value of standardizing ergonomic scores within the dimensions of age and gender. The Borg score was noted to have the highest point estimates. These results are expected, as Dennis et al. (2004), and Krause et al. (2004), reported that an increase in workload should logically lead to an increase in injuries (8,9).

4.1. Advantages and limitations

In studies of this type, there is always a potential for bias; however, numerous efforts were incorporated to minimize bias. One of the limitations of this study was the low response rate (32.5%). Potential response bias was reduced by inversely weighting observed responses by probabilities of response, estimated as a function of janitor characteristics provided by SEIU L26 (Horvitz and Thompson, 1952). Lack of reporting of occupational injury outcome in questionnaires, as described by Braun and Gerberich (Braun et al., 1994), is a potential issue with the research process. Workers may be unclear about when and where to report outcomes and, instead, rely on their own perceptions of when to report, based on event circumstances (Pompeii et al., 2016) or severity. Underreporting may also be related to unwillingness to reveal incidence (Braun et al., 1994; Mbaisi et al., 2013) due to fear of retribution. Research has found "considerable evidence of fear of reprisal for reporting injuries." (Lipscomb et al., 2013) Other potential barriers to reporting include having too much time pressure to take time to report, fears of the report never being read, and the mindset that injuries are part of the job. In this study, most of the janitors completed the surveys in the workplace, suggesting that the factors preventing them from reporting injuries to management may also have caused under-reporting of injuries on the questionnaire. In addition, questionnaire facilitation by union stewards, in the current study, may have potentially introduced information bias in the responses; however, these stewards received targeted training from the research team relevant to the questionnaire administration in an attempt to ameliorate this potential bias. The Janitor response rate to the surveys may have

been adversely affected by language limitations, lack of time to respond or distrust that the information was truly anonymous.

The ability to generalize from a laboratory simulation to the real world is always problematic. Bucholz et al. have suggested that work-sampling methods may give better representation of the work performed (Buchholz et al., 1996). Another limitation is that the accuracy of the judgment of angles by observers is not perfect (Lu et al., 2012; Uan et al., 1999). However, there is some indication that assessment of postural angles using the REBA tool is consistent, since a moderate level of inter-rater reliability (see section 2.5) and a high level of intra-rater reliability (Schwartz et al., 2019) were both observed in this study. Assessment of the accuracy of the postural angles, as assessed with REBA against the actual angles, is beyond the scope of this paper.

The SWEEP study questionnaire's cross-sectional collection of data could have introduced incidence-prevalence bias (or Neyman bias) (Moyses)Nieto (2014); Levin (2006); Hill et al. (2003). This bias is caused by potential early drop out before the study is initiated or before the data is collected which can lead to differential drop outs between people prone to injury and those who are not (Grimes and Schulz, 2002). Neyman bias may be minimized by the short recall period of the study and the reduced likelihood of job-changing injuries. Similarly, this shortened recall period may reduce the healthy worker effect – a concern with many occupational studies (Shah, 2009). Recall bias was minimized through the study design, in which the total study period of one year was divided into two six-month recall periods to limit this error (Coughlin, 1990; Connelly et al., 2000; Pannucci and Wilkins, 2010; Yoshihama and Gillespie, 2002).

There were many advantages associated with the SWEEP study. This involved participant-driven research, in that the subjects were enthusiastic about the project and requested assistance to study the potential effect of their workload on injury. The number (n = 720) of ergonomic assessments conducted is unusually large and advantageous for a study of this type. Access to the janitors, through facilitation by the SEIU L26, greatly assisted the feasibility and conduct of the research. Being able to consult with active janitors enabled the research team to design a study that was responsive to the needs of the target population.

5. Conclusions

This study identified heavy ergonomic workload levels among janitors as being positively related to injury occurrence. It is important to note that, while the REBA and Borg scores combined with task-frequency are very highly correlated, analysis demonstrated that the Borg should be used first as a screening tool before the more labor-intensive REBA is applied.

Directions for future research include further studies of larger populations and development of potential interventions to reduce injuries. Disrupting either the frequency of the janitorial tasks or their intensity, as well as consideration relevant to equipment redesign and alteration of task conduct, are potentially fruitful avenues. Unlike the Borg, the REBA has many components. It is possible to see which factors have the largest impact on the REBA score. This current study involved a cross-sectional design, enabling comparisons between the workload exposures and the outcome of injury. It will also be important to examine relations between various combinations of task frequencies and intensity (as measured by REBA and Borg) and injury outcome. Other understudied occupational populations, with exposures similar to janitors, are also important to address in a comparable manner.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apergo.2019.102874.

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