Physiological, subjective and postural loads in passenger train wagon cleaning using a conventional and redesigned cleaning tool

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Abstract

Methods: In this study, cleaning process was studied and analyzed with special reference to cleaning tools. A group of 13 professional cleaners participated in this study. While they performed their normal tasks, their oxygen consumption, heart rate, rating of perceived exertion and postural data were obtained. The perceived exertion during cleaning task using the “redesigned cleaning tool” was less than that of the “conventional cleaning tool”. The oxygen consumption when cleaning with the redesigned tool (mean 0.84 l/m, SD ± 0.17) was significantly less ($p<0.05$) compared to the conventional cleaning tool (mean 0.94 l/m, SD ± 0.18). Heart rate was also found significantly lower using redesigned cleaning tool (mean 101 bpm, SD ± 11.10) compared to that of conventional cleaning tool (mean 105 bpm, SD ± 12.59) ($p<0.05$). Using redesigned cleaning tool the trunk postural load was also found significantly less than that of conventional cleaning tool ($p<0.05$). It is concluded that redesigned cleaning tool allowed cleaners to maintain more upright posture when cleaning, which reduced biomechanical load.

Relevance for Industry: There is need to develop ergonomic criteria or recommendation to enable manufacturers of cleaning equipment to specify and evaluate usability qualities when formulating user requirements for new cleaning tools.

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Keywords: Ergonomics; Redesigned cleaning tool; Oxygen consumption; Heart rate; Perceived exertion

1. Introduction

It has been repeatedly stated that the stress experienced on exposure to repetitive work can give rise to low job-satisfaction, poor job
performance and impaired well being (Cox, 1980). Many factors of work and environmental conditions affecting professional cleaners increase the risk of occupational diseases (i.e., musculoskeletal disorders). Among them are inappropriate and poor working postures, lack of task variation, poor ergonomics design of the work places, cleaning tools and the task including work organization. In professional cleaning most of the work is done by using long-handled equipment (25–35% of the work hours) (Hopsu et al., 1994). Cleaning floors with a wet mop is one of the most time-consuming and physically demanding tasks among professional cleaners. During wet mopping a long-handled mop is moved across the floor in the shape of figure of eight while walking backwards slowly. In Finland, wet mopping is not common, as it has been determined to have a heavy physical demand on workers from measurement of heart rate, the evaluation of work postures and perceived load (Krüger et al., 1997). The cleaners have also rated it as a strenuous task. Therefore, most interventions have focused on this task and during the few last decades many new tools and techniques have been introduced (Søgaard et al., 1995). A research study done by Hagner and Hagberg (1989), among 11 professional female floor cleaners showed that the “figure-of-eight” method is more strenuous than the “push” method requiring high oxygen consumption.

In professional cleaning static postural load is frequent, and particularly, poor work postures are common for the back and arms. Some of the studies for different types of cleaning (Louhevaara (1997), Hopsu (1997) and Hopsu et al. (1994)) have found an average of 36–56% of working hours spent bent forward and/or with a twisted back, about 24–43% of working hours with one arm or both arms above shoulder level, and cleaners also spend 3–14% of their working hours in a squatting posture.

A literature review indicates that there has been no study published on professional cleaners in passenger train wagons related to the floor-cleaning tool. Cleaning of passengers train wagons is different compared to other cleaning jobs. Performing cleaning activities in passenger train wagons is very difficult to do, as passenger train wagons have limited room. To clean and see under the lower berth requires strenuous activities. As a result, cleaners have to adopt awkward working postures (Fig. 1).

Some excellent studies have been done on the physical aspects of professional cleaning by Hopsu et al. (1994) and Hagner and Hagberg (1989) and Søgaard et al. (1996). They indicated that the most important risk factors involved in the physical work of professional cleaning are namely, static muscular work, especially in terms of bent and/or twisted posture of the back and repetitive movements of the arms and hands with a high output of force. From an ergonomics point of view existing tools, task/methods, working environment needed to be better designed in order to reduce occupational injuries among cleaners. From the workplace analysis in the passengers train wagon, it was found that most of the awkward working postures among cleaners were due to the workstation and existing tool. Changing workstation inside the train wagon was not possible due to lack of

![Fig. 1. Working posture while cleaning the passenger train wagon with the conventional cleaning tool](image)
flexibility in design. Changing the tool was an obvious and cost effective ergonomics strategy. Consequently, the cleaning tool was redesigned and compared against the conventional tool for postural, physiological and subjective load on cleaners. The specific objectives of the study were to determine the following:

1. Whether oxygen consumption and heart rate could be reduced when using redesigned cleaning tool in comparison to the conventional cleaning tool.
2. Whether redesigned cleaning tool reduced the trunk angle compared to the conventional cleaning tool.
3. Whether the cleaners perceived less exertion while using the redesigned cleaning tool in comparison to the conventional cleaning tool.

2. Method

2.1. Subjects

Thirteen healthy professional cleaners (12 females and 1 male) participated in the study. Their professional experience ranged from 1 to 21 years (Table 1). Twelve of the cleaners were right-handed and one left-handed. One week prior to the study, cleaners practiced with both cleaning tools.

2.2. Cleaning tools

A commercially available long straight handle-cleaning tool for floor mopping was used as a conventional cleaning tool. The length of the tool could be adjusted between 105 and 190 cm. The redesigned cleaning tool was bent at three points, upper, middle and lower part of the tool in such a way that it produced an arc shown in Fig. 2.

The redesigned cleaning tool allowed neutral wrist posture while mopping the floor as compared to the conventional cleaning tool where flexion and extension of the wrist was needed while mopping the floor (Fig. 3). The arrow in the figure shows the movement of the wrist/hand using each tool.

![Fig. 2. Cleaning tools: (a) conventional cleaning tool; (b) redesigned cleaning tool.](image)

Table 1
Characteristics of cleaners sample \((n = 13)\)

<table>
<thead>
<tr>
<th>Subject characteristics</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>38</td>
<td>12.9</td>
<td>55</td>
<td>20</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163</td>
<td>9.6</td>
<td>180</td>
<td>150</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.2</td>
<td>11.7</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Employment (yrs)</td>
<td>5.6</td>
<td>6.95</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>Maximum oxygen uptake (l/min)</td>
<td>2.60</td>
<td>0.29</td>
<td>3.16</td>
<td>2.04</td>
</tr>
<tr>
<td>Maximum oxygen uptake (ml/kg/min)</td>
<td>42</td>
<td>6.06</td>
<td>54.55</td>
<td>27.89</td>
</tr>
<tr>
<td>Resting heart rate (bpm)</td>
<td>72</td>
<td>10</td>
<td>90</td>
<td>56</td>
</tr>
</tbody>
</table>
2.3. Procedure

The maximum oxygen uptake of the cleaners was determined by performing a test on a bicycle ergometer (Tuntri, 850 ECB PRO, Ergometer). Cleaners were asked to cycle at a steady rate (60 revolutions per minute) of 50 W for 2 min with subsequent increases of 50 W every 2 min until exhaustion (Price and Campbell, 1997). The cleaners were asked to try to maintain a certain pedal frequency of 60 rpm by using a metronome, which produced a sound signal (Åstrand and Rodahl, 1986). The measured values in liters per minute (l/m) as well as milliliter per minute per kilogram (ml/m/kg) of gross body weight were obtained by using a MetaMax II. The MetaMax II is a multifunctional metabolic measurement system, which can be used as a portable system to measure under real conditions or as a stationary system in a laboratory. It measured oxygen consumption, carbon dioxide output, ventilation, heart rate, ambient temperature and pressure. The devices were calibrated before each use.

To minimize the effects due to the fatigue from the bicycle ergometer test, the cleaning tests were performed after three days (Mackinnon, 1999).

Cleaners were randomly assigned the tool to use in each test. Cleaners had a rest of 10–15 min before starting the initial test. They cleaned an area of 52 m² where dry sand and papers were used as materials to be cleaned during the 15-min test. The cleaners were required to maintain a fixed work pace. During the test, oxygen consumption was recorded every 10 s and heart rate was recorded every 5 s (Bridger et al., 1997).

After the first test, the cleaners had a rest interval of 15–30 min during which the resting heart rate was obtained (Bridger et al., 1997). The
protocol was repeated for the second test, but the alternative tool was used at the same pace. Cleaners were asked to rate their perceived exertion while performing the test. The Borg’s scale was used for rating. Just 30 s before the end of each test, cleaners rated their perceived exertion on the Borg scale (Borg, 1982, 2001). Each cleaner received a standardized verbal and written explanation of how to use the Borg scale prior to the test.

The tests were recorded on videotape in profile for posture and biomechanical analysis of the cleaner’s postures during the tests. Postural angles (maximum trunk bending) were assessed using photographs in profile of cleaners reaching under the bed while cleaning with both tools (Fig. 4). The reference point was lumbosacral (L5/S1) and cervical (C 7) joining the center of gravity line (Hagner, 2001).

2.4. Analysis

All values of measured variables are expressed as means and standard deviation. A paired t-test was used to determine differences between the oxygen consumption, heart rate and postural variable. A Sign test was used to determine the differences in perceived exertion. Probability values of $p < 0.05$ were accepted as being statistically significant.

3. Results

Table 2 shows the results of the analysis of average oxygen consumption in l/m and ml/m/kg of body weight average heart rate in beats per minute (bpm), perceived exertion and percent maximum oxygen uptake required to do the job.
using two cleaning tools. Average oxygen consumption and heart rate were found to be significantly different for the conventional cleaning tool compared to redesigned cleaning tool ($p < 0.05$).

The mean value for oxygen consumption (VO$_2$) was 0.94 l/min with the conventional cleaning tool and 0.84 l/min with the redesigned cleaning tool. The heart rate (HR) mean value was 105 bpm with the conventional cleaning tool and 101 bpm with the redesigned cleaning tool (Table 2).

The cleaners used 36% of their maximal oxygen uptake capacity while cleaning with the conventional cleaning tool. The corresponding percentage for the redesigned cleaning tool was 31% ($p < 0.002$).

The mean perceived exertion while cleaning with the conventional cleaning tool was 13 on the 20-point Borg scale and for cleaning with the redesigned cleaning tool was only 11 ($p < 0.001$). From using the $t$-test for postural analysis a significant difference was found for the angle of the trunk between conventional and redesigned tool use ($p < 0.05$). The mean angle of trunk bending while using the conventional cleaning tool was 87° and with the redesigned cleaning tool was 50° ($p < 0.001$) (Fig. 5).

4. Discussion

Work requiring the oxygen uptake from 0.50 to 1.01 l/min is considered as moderate (Åstrand and Rodahl, 1986). In the present study, the oxygen consumption (l/m) had a higher mean value (0.94 l/m) while cleaning with the conventional cleaning tool, which was statistically significantly different compared to redesigned cleaning tool (0.84 l/m). Nonetheless, cleaning with both tools can still be considered as moderate work (Åstrand and Rodahl, 1986) and not heavy as previously suspected. The International Labor Organization (ILO) suggested 33% of the maximal oxygen consumption (VO$_2_{max}$) as an acceptable load during 8-h of working day (Vanwoaterghem, 1986). From this study, the cleaners used 36% of their VO$_2_{max}$ while using the conventional cleaning tool and 31% while using the redesigned cleaning tool, which is statistically significant. This means that by using redesigned cleaning tool the cleaners can work 8-h shift within
There was significant reduction in heart rate during cleaning with redesigned tool as compared to conventional tool, which may be due to postural factors. The possible reason could be that in upright cleaning posture, the large group of muscles of upper part of the body is not engaged as in the bending posture (Bridger et al., 1997).

Heart rate increases linearly with oxygen consumption in response to increasing workload (McArdle et al., 1991). Some studies found a linear relationship between heart rate and oxygen consumption during non-steady state activities however tests were limited to progressive incremental exercise (Bernard et al., 1997). Findings from this study also showed the significant relation between heart rate and oxygen consumption.

No correlation was found in this study between heart rate and oxygen consumption and perceived exertion. In one study Datta et al. (1983), found high positive correlation between heart rate and perceived exertion. However, Mital et al. (1993) investigated workload and fatigue in highly trained cleaners and found a difference between ratings of perceived exertion and objective measures with the cleaners underestimating the actual workload. In this study it might be possible that cleaners underestimated the actual workload with perceived exertion. However, comparative values show an advantage for the redesigned tool. Borg (1982) himself stated that the close relationship between perceived exertion and heart rate was not intended to be taken literally since the latter is only one indicator of exercise strain.

The cleaners rated the conventional cleaning tool more strenuous than the redesigned cleaning tool while cleaning the wagon’s floor. Cleaning with conventional cleaning tool was assessed to the scale value 13 (somewhat hard) compared to redesigned cleaning tool to the scale value 11 (light) according to the Borg RPE scale. Most likely very frequent and excessive bending of the torso of the cleaners created greater biomechanical loads on the back compared to the redesigned cleaning tool, and muscles had to work with higher forces against center of the gravity while bending. This could be the possible reason that cleaners perceived higher exertion in using conventional tool compared to redesigned cleaning tool (Kumar, 2001).

The study reveals that the cleaners bent less when they used the redesigned cleaning tool. The conventional cleaning tool required frequent and excessive bending in order to clean the lower berth of the wagon compared to redesigned cleaning tool.

This study focused only on the floor cleaning task, even though the floor cleaning task does not represents the entire cleaning task required for the passenger train wagon, but it was one of the major tasks. Though, the upper limb stress was not systematically studied in the present study, however, it was observed in video recordings and also reported from the cleaners that excessive extension and flexion of the wrist/hand required with conventional cleaning tool were completely eliminated while using redesigned cleaning tool.

5. Conclusions

It can be concluded that floor cleaning in the train wagons is associated with moderately high cardiovascular load and high frequency of stressful working postures. The introduction of the redesigned cleaning tool allowed cleaners to maintain more upright posture while cleaning, which reduce biomechanical and physiological loads on them.

References


with a conventional and two-handled ('levered') shovel. Ergonomics 40, 1212–1219.


