Ergonomic assessment of suspended scaffolds

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Abstract

Work on scaffolds is usually associated with traumatic type injuries. However, operating that type of equipment can also contribute to overexertion injuries, especially in manually operated suspended scaffolds. Since this equipment is largely used both in Brazil and other developing countries for painting and coating building facades, this study presents an ergonomic assessment on the operation of two types of suspended scaffolds. They are referred to as light scaffold and heavy scaffold—the difference lying in their dimensions and number of gears. The assessment criteria were: workers’ perceptions of effort; body posture assessment (OWAS method); heart rate elevations (HRE); percentage of the available heart rate range (PHRR); scaffolds’ speed and, repetitiveness of movement in the scaffolds’ levers. Workers preferred the light scaffold because it moved up to eight times faster than the heavy scaffold. However, the study’s results indicated that the operation of both types is much too physically demanding. For instance, HRE was 52 beats per minute (bpm) and PHRR was 50.7% on average for workers operating the light scaffold. Concerning the heavy scaffold, HRE was 45 bpm and PHRR was 42.2% on average. All of those values are substantially higher than the acceptable limits of 35 bpm for HRE and 33% for PHRR proposed in the literature. Failures in the scaffolds’ design as well as the lack of attention directed towards ergonomics in regulations were determined to be relevant root causes for detected poor working conditions.

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1. Introduction

Historically, less emphasis has been focused on health issues in the construction industry in favour of the more immediate, high profile (and perhaps more easily solvable) safety issues. This is due to a number of factors, such as: the sizeable, temporary and mobile workforce; many workers are not directly employed; the lack of health expertise within industry; benefits of health management are not immediate and are consequently difficult to demonstrate (Gibb et al., 1999). However, several studies have pointed out high incidence of health problems in this industry (Everett, 1999; Gibb et al., 1999). In 1995, the UK’s self-reported work-related illness survey found an estimated 134,000 construction-related workers reported a health problem caused by their work, resulting in an estimated 1.2 million days lost in a workforce of 1.5 million (Horne et al., 2003). Since construction projects are becoming more complex, with time and cost constraints more severe, professional burnout has also become an increasing concern in this industry (Lingard and Sublet, 2004). Besides, construction work is, by its very nature, a problem in ergonomics. For example, installing floors and ceilings requires work at floor and ceiling height which, by definition, is ergonomically hazardous since ceilings have to be above shoulder level and floors below knee height (Schneider and Susi, 1996).

Despite the little attention that construction industry has given to health hazards, their control measures are fairly well known. In fact, a number of studies have dealt with ergonomic assessments and development of engineering controls for typical construction activities (Everett, 1999; Schneider and Susi, 1996). However, there is lack of studies concerning technologies that are extensively used in developing countries. For example, manually operated suspended scaffolds that are largely used in Brazil for
painting and coating building facades have not been examined. In Brazil, both powered suspended scaffolds and tower scaffolds are still used at a minor extent, mostly in major construction projects. In the literature review carried out for this study, no references on previous ergonomic assessments of suspended scaffolds were found. However, Cutlip et al. (2000) and Hsiao and Stanevich (1996) carried out biomechanical assessments on assembly and disassembly of tower scaffolds. Those studies identified tasks and activities that increased the risk of overexertion injury associated with the erection and dismantling of frame scaffolds. Also, Fang et al. (2004) compared the level of nervousness of workers at bamboo and metal supported scaffolds in Hong Kong. Based on pulse frequencies measurements, they concluded that people are usually more nervous on bamboo tower scaffolding than on metal tower scaffolding.

Work on scaffolds, whatever the type, is usually associated with fall hazards. An analysis of approximately 3000 accident reports in Brazilian construction sites carried out by Costella (1999), showed that falls from scaffolds, whatever the type, accounted for nearly half of all serious accidents (46.3% of the total). Because of this high incidence of traumatic injuries of this type, NR-18 (Work Conditions and Environment in the Construction Industry), the main safety regulation related to the construction industry in Brazil, focuses mainly on prescriptive requirements regarding the structural design of scaffolds. Ergonomic issues, not only concerning scaffolds, are not directly dealt with by NR-18 (Saurin et al., 2000). Moreover, suspended scaffolds in Brazil are usually manufactured on site using craft methods. Besides that, they are frequently made of reused material often refused at the construction site by the contractor’s carpenters, and metal supported scaffolds in Hong Kong. Based on the context described above, it seems necessary to go beyond safety risks and to investigate ergonomic issues associated to the operation of suspended scaffolds. The improvised way that suspended scaffolds are usually manufactured, the fact that their operation is a labor-intensive-task and the absence of ergonomic requirements in NR-18 indicate that relevant ergonomic hazards are likely to exist. Thus, this paper aims to assess the extent to which operating suspended scaffolds is a demanding task as well as to identify the underlying reasons of the detected poor working conditions.

2. Research method

Due to the increasing incidence of musculoskeletal disorders among bricklayers who were coating the building’s external envelope using scaffolds, an ergonomic assessment was requested by a major building contractor in Porto Alegre, South of Brazil. Government inspectors also had intensified inspections at the contractor’s sites. In particular, they demanded the compliance with a NR-18 requirement that established that working platforms should be capable of supporting a minimum of at least 200 kgf (440.5 lb). Even though site managers pointed out that the compliance with that requirement would result in over sizing the scaffold, the structural design of the scaffold was not focused in this study.

Assessment was based on the following five parameters: (a) workers’ perceptions about the working conditions; (b) adopted work postures during both coating activities and scaffolds operation; (c) physical demand of both coating activities and scaffolds operation; (d) estimation of scaffolds’ speed; and (e) measurement of task repetitiveness during the operation of the scaffolds’ levers. It is worth emphasizing that parameter (d) was considered because the scaffolds’ speed could have an impact on both the length of time workers were exposed to hazardous conditions and the type of scaffold they preferred. The data collection procedures are presented in detail below.

2.1. Overview of the working environment and tasks

2.1.1. Description of the scaffolds studied

This study was conducted in two residential buildings where suspended scaffolds were used for facades’ coating work. The scaffolds were classified as either light or heavy. Both types could be easily distinguished through visual inspection. This distinction was based on the features presented in Table 1. Heavy scaffolds were fully assembled at the construction site by the contractor’s carpenters, except for the gears, which were purchased from an external vendor. Light scaffolds were fully pre-assembled, including gears, planks and the guardrail system and were provided by the same vendor.

Fig. 1a shows the operation of a heavy scaffold. It can be noticed that the worker has adopted a device to make the lever longer. This was required to reduce push and pull forces. Fig. 1b shows the lever of a light scaffold, in which a similar device was also adopted. The dimensional difference between both types of scaffolds is illustrated by Fig. 1c, which shows a frontal view. In this view, the light scaffold (on the left) was in front of a blind wall. Note that both access and loading of materials were limited to an adjoining heavy scaffold.

Table 1

<table>
<thead>
<tr>
<th>Basic features of the scaffolds studied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light scaffold</td>
</tr>
<tr>
<td>Width</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Number of gears</td>
</tr>
<tr>
<td>Length of cable per gear</td>
</tr>
<tr>
<td>Weight of each gear</td>
</tr>
<tr>
<td>Guardrail system</td>
</tr>
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</table>
2.1.2. Description of the activities carried out from the scaffolds

In both studied buildings, the majority of the scaffolds were of the heavy type. During regular work activities (i.e. coating the wall), the heavy type is usually occupied by two people and the light type by one. However, upward movement along the whole building height, which was necessary before starting a new layer of the coating, was normally carried out by a single worker for both scaffold types. The basic equipment required for coating tasks, which was kept on the scaffolds, comprised mortar boxes (see Fig. 1a), spade, ruler, bucket and paintbrush. Powered machines for mortar production were available in every floor in order to reduce materials’ moving.

2.2. Workers’ perceptions

Since workers’ perceptions may provide key insights on their working conditions, Fogliatto and Guimarães (1999) proposed a participatory method for eliciting this information. This method, used in this study, consists of interviews and questionnaires as described in the following sections.

2.2.1. Interviews

Interviews were conducted with all 21 workers who used scaffolds to accomplish their work. They were divided into two groups: group 1, formed by 10 workers; group 2, formed by 11 workers. The interviews, which lasted approximately 30 min, were tape-recorded. During the interviews, workers were asked to comment on both positive and negative aspects of their work, not only about their workstations. They also were encouraged to make suggestions for solving any problems that they surfaced.

2.2.2. Questionnaires

The qualitative data obtained from the workers during the interviews provided the basis to develop the study’s questionnaire. This methodology allowed the workers an opportunity to quantify and prioritize any identified problems. A 15 cm scale with three milestones (one in the beginning, one in the middle and another one at the end of the scale) was used. The questionnaire consisted of 29 questions grouped in five sections: work environment, workstation, production planning, workload, pain and discomfort. Those who answered the questions were the same workers that had been previously interviewed. The Cronbach’s technique was used to determine the internal consistency of the questionnaire. This α indicates the extent to which the scale was understood and points out whether the data are minimally reliable. An acceptable result is achieved when α is equal or higher than 0.55. The Kolmogorov–Smirnov test showed that more than 52% of the variables (p = 0.200) were normal and the Levene test showed that variables were homogeneous (p ≥ 0.551). Therefore, a one-way analysis of variance (ANOVA) was conducted to evaluate whether there was statistical difference among the question’s means. A statistical significance level of 95% was adopted.

2.3. Work posture assessment

The work posture assessment was supported by the WinOWAS® software (Kivi and Mattila, 1991). This tool is based on the Ovako Working Posture Analysis System (OWAS), which covers the most common and easily identifiable work postures for the back, arms and legs. The type and frequency of the different postures assumed during work are recorded along with an estimate of the load handled by the subject being observed. The basic idea of this observational technique is to collect data through postural observations (usually 100 observations) made at set intervals (usually at every 30 s) over a set time period (Mattila and Vilkki, 1999). According to this method, the risk of injuries due to awkward work postures can be classified into the following four categories:

(a) category 1: normal and natural postures with no harmful effect on the musculoskeletal system—no action required;
(b) category 2: postures with some harmful effect on the musculoskeletal system—corrective actions required in the near future;
(c) category 3: postures have a harmful effect on the musculoskeletal system—corrective actions should be done as soon as possible;
(d) category 4: the load caused by these postures has a very harmful effect on the musculoskeletal system—corrective actions for improvement required immediately.

Four workers were observed performing different tasks: regular coating tasks carried out from both light and heavy scaffolds; raising and lowering both types of scaffolds. Concerning coating tasks, body postures were registered every 30 s, as proposed by the OWAS method. The observed work cycles consisted of approximately 50 min (out of an 8 h shift), which is likely to be sufficient to capture most of the subtasks performed. Thus, a 100 observations were made for each situation of coating, including the positions of back, arms and legs, as well as the load handled. However, more accurate data could have been collected if a longer length of time had been considered, since the facades were not fully uniform. The observations did not take into account the whole work cycle to coat a whole floor, since this task could take days or weeks.

Concerning raising and lowering scaffolds, postures were registered every 15 s during 25 min. In fact, for each type of scaffold, during about half of this time workers were lowering the scaffold and in the remaining time they were raising it. This length of time was certainly sufficient to capture all typical subtasks, since moving scaffolds was a very repetitive task (see Section 3.4). Moreover, a longer period of observation was not practical due to the high physiological demand of the moving task (also see Section 3.4). It is important to note that, as expected, workers sometimes paused during the push–pull cycles.

2.4. Physiological demand assessment

The physiological workload was indirectly estimated based on the heart rate recorded with a portable monitor (Polar S610). This device has electrodes that are attached to the subject’s chest to detect signals from the heart that are transmitted to a wrist receiver. After installing the electrodes, the person was asked to stay seated for 15 min to obtain a resting pulse (i.e., the heart rate with no workload). Then, the heart rate during working activities (i.e., the working pulse) was monitored and recorded. Since the monitor had no computer interface, heart rate was read (i.e., the working pulse) was monitored and recorded. Since the monitor had no computer interface, heart rate was read and recorded directly from the reception unit every 5 min. Meanwhile, a member of the research team videotaped the tasks under observation. Thus, data was obtained that would allow future correlation between heart rate and task performance. These tapes were also used for body posture analysis with the WinOWAS® software.

Workload classifications methods based on oxygen uptake, peak heart rate, and average heart rate, such as the one proposed by Astrand and Rodahl (1986) were not adopted in this study. This decision was made considering that the mentioned parameters are too sensitive for individual differences such as age, weight, and fitness. Therefore, for this specific study, the workload classifications could be biased. To minimize the influence of the individual differences, the main criteria adopted for the physiological demand analysis was the heart rate elevation (HRE). It is defined as the difference between average heart rate during work (working pulse) and the resting heart rate, in beats per minute. Kroemer and Grandjean (2000) proposes 35 HRE as the limit to be accepted for continuous work for males. In addition to HRE, another criterion adopted for physiological demand assessment was the percentage of the available heart rate range (PHRR), which can be frequently equated to the percentage of the maximum aerobic work capacity for the work being performed. PHRR is derived from the Eq. (1) (Eastman Kodak, 1986):

$$\text{PHRR} = \frac{\text{HR task average} - \text{HR rest}}{\text{HR max} - \text{HR rest}},$$  \hspace{1cm} (1)

where * the predicted maximum heart rate is roughly calculated as 220—age in years (Rodgers, 1986).

According to Eastman Kodak (1986), a PHRR value of 33% is an appropriate upper limit for most industrial workers, considering an 8-h shift. This limit is adopted as the basic criteria for this study.

2.5. Estimation of scaffolds’ speed

An experiment was devised to estimate the speed of each type of scaffold when manned by both one worker and two workers. The objective was to identify which scaffold exposes the worker to a longer and more strenuous effort. Workers were asked to raise and lower the light scaffold along two floors (about 10.0 m). The heavy scaffold (a six-gears model) was raised and lowered just for 1.6 m. For all measurements, the chronometer was turned off at the end of the downward movement and was restarted when the upward movement began.

2.6. Evaluation of the repetitiveness in the operation of the scaffolds’ levers

The working postures study described in Section 2.3 was partly based on a 25 min filming of workers raising and lowering scaffolds. Based on such films, the researchers registered the total number of push–pull cycles of the scaffolds’ levers that were carried out during the whole filming. By dividing this quantity by 25 min, the average number of push–pull cycles per minute undertaken during the filming was calculated. The measurement was taken for both types of scaffolds, both for lowering and raising the equipment.

3. Results

3.1. Workers’ perceptions

During the interviews, the workers reported 24 problems. Table 2 shows how the data were organized.
As a whole, the problems reported could be grouped into the following four categories:

(a) overexertion both during coating and scaffolds’ moving activities. When the elevation of the scaffold was adjusted, the operator became physically exhausted. He was no longer able to perform other activities and had to leave the site earlier in the day;

(b) badly designed scaffolds, which made the equipment too heavy. For instance, workers questioned the effectiveness of the following design decisions: the type of wood chosen to manufacture the planks, which was reported to be too heavy; the height of the guardrails, which was higher than NR-18 prescriptions (1.20 m); and the little available space among the gears, which restricted movement on the scaffold. Workers also pointed out that the steel cable that suspended the scaffold was longer than necessary. Thus, unnecessary weight was added to the scaffold. The safety manager stated that this problem happened both because the cable supplier provided standardized cable lengths and because the cables were re-used in buildings that had different heights;

(c) failures in safety planning and control. For instance, improper location of lifelines made it difficult to move on the scaffold. Concerning product design failures, a building’s main facade had two walls with just 65 cm of width (Fig. 2). Therefore, it was not possible to install scaffolds and workers from the adjacent scaffolds were required to coat these walls and to do this, they had to adopt both unsafe and awkward postures to reach the wall. In fact, due to the difficulty in moving the scaffolds, violations such as using boxes to increase the working level height of employees were a commonplace at most scaffolds, not only in those placed in restricted areas;

(d) inadequate personal protective equipment (PPE)-related problems, such as dermatitis caused by insulation on the body areas around the harness.

3.2. Questionnaires

The Cronbach $\alpha$ statistic was low ($<0.55$) for the questions regarding the workers perception of the environment ($\alpha = 0.31$). The values of $\alpha$ for the other groups of questions were satisfactory: workstation (0.72); production planning (0.56); physical demand (0.77); pain and discomfort (0.85). Fig. 3 shows the degree of workers’ satisfaction concerning their workstations. In Fig. 3, as
well as Figs. 4–6, the bars with the same pattern identify items whose mean values had no statistical difference. In Fig. 3, it can be noticed that problems due to poor scaffolds’ design (weight of heavy scaffolds, excessive length of cable on the gears, and little space among gears) had lower means when compared to issues related to the coating tasks (such as the availability of tools and equipment). These results might indicate that failures in the scaffolds’ design have a stronger impact on workload than the coating tasks.

Fig. 4 shows the degree of satisfaction concerning production-planning issues. The structure being out of plumb was noticeably the main focus of dissatisfaction. This condition implied that both additional workload and extra material to coat the facades’ walls were required.

Fig. 5 shows how workers perceived the workload to complete the tasks. Typical coating tasks (e.g. placing mortar and loading mortar into boxes) were perceived as being less demanding than moving scaffolds. This result is consistent with workers’ perceptions about their workstations shown in Fig. 3.

Fig. 6 shows workers’ perceptions on pain and discomfort. The arms, back and legs were identified as the areas of discomfort for this work environment, what is coherent with the type of activities performed.

3.3. Work posture assessment

Fig. 7 shows the postures observed while moving a heavy scaffold. The analysis focused on those situations in which postures are classified either as categories 2, 3 or 4. Fig. 7 illustrates that the back and legs were in the most awkward postures during the heavy scaffold operations. Observations also revealed that backs were bent 54% of the time. In an additional 13% of the time backs were bent and twisted. Also, the worker was standing with both knees being bent 36% of the time and in 16% of the time one knee was bent. All these postures were classified either as categories 2 or 3.

Back and legs were also the most vulnerable body parts in the operation of the light scaffolds. Backs were bent 54% of the time and both bent and twisted 9% of the time.
Also, the worker was standing with both knees being bent 34% of the time. All these postures were classified either as categories 2 or 3.

Fig. 8 shows the overall distribution of postures for each work situation analyzed. Backs, arms, legs and workload altogether are considered. Comparing both the light and heavy scaffolds’ moving and regular work, the higher incidence of postures categorized as 3 and 4 took place on the heavy scaffold. This might be due to the fact that the heavy scaffolds’ levers had a wider rotation angle than the light scaffolds’ levers, which implies additional bending for both back and legs. Field measurements indicated that the heavy scaffolds’ levers rotated about 93°, while the light scaffolds’ levers rotated about 65°. It should be noted that direct observation of the coating tasks pointed out two biomechanical problems that were not detected through the OWAS method: (a) during placement of mortar on walls the arms remained a long time a little below the shoulders level; and (b) the arms were not supported on a rigid surface during coating tasks.

3.4. Physiological demand assessment

Table 3 shows the results of the physiological assessment for each worker observed. It can be noticed that HRE was below 35 just in two out of the 12 measurements. The percentage of the available heart rate range (PHRR) was below 33% in just three out of the 12 measurements. Also, the physiological demand was not reduced below these limits when two workers operated the equipment together.

Table 4 summarizes the workload assessment. According to the criteria adopted, moving the light scaffold was slightly more demanding than moving the heavy scaffold—15% more demanding based on the HRE criteria and 20% more demanding based on the PHRR criteria.

The greater physiological demand of the light scaffold is likely to be a result of the higher incidence of static work in back and legs when moving that equipment. Static work is characterized by the maintenance of a posture for a long period of time and it is known to be more fatiguing than dynamic work (Kroemer and Grandjean, 2000). This conclusion is based on two data: (a) the rotation angle of the light scaffolds’ lever is smaller, as previously mentioned; and (b) the repetitiveness of push–pull cycles in the

Table 3

<table>
<thead>
<tr>
<th>Task (number of the worker)</th>
<th>Age</th>
<th>Predicted maximum HR</th>
<th>Resting HR</th>
<th>Average HR</th>
<th>HRE</th>
<th>PHRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving light scaffold (1)</td>
<td>38</td>
<td>182</td>
<td>89</td>
<td>160</td>
<td>71</td>
<td>76.3</td>
</tr>
<tr>
<td>Moving light scaffold (2)</td>
<td>29</td>
<td>191</td>
<td>76</td>
<td>104</td>
<td>28</td>
<td>24.3</td>
</tr>
<tr>
<td>Moving light scaffold (3)</td>
<td>53</td>
<td>167</td>
<td>87</td>
<td>124</td>
<td>37</td>
<td>46.3</td>
</tr>
<tr>
<td>Moving light scaffold (4)</td>
<td>44</td>
<td>176</td>
<td>77</td>
<td>146</td>
<td>69</td>
<td>69.7</td>
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<tr>
<td>Moving light scaffold (5)</td>
<td>18</td>
<td>202</td>
<td>74</td>
<td>138</td>
<td>64</td>
<td>50.0</td>
</tr>
<tr>
<td>Moving light scaffold (6)</td>
<td>34</td>
<td>186</td>
<td>79</td>
<td>135</td>
<td>56</td>
<td>52.3</td>
</tr>
<tr>
<td>Moving light scaffold (7)</td>
<td>29</td>
<td>191</td>
<td>85</td>
<td>121</td>
<td>36</td>
<td>34.0</td>
</tr>
<tr>
<td>Regular work at light scaffold (8)</td>
<td>25</td>
<td>195</td>
<td>89</td>
<td>124</td>
<td>35</td>
<td>34.9</td>
</tr>
<tr>
<td>Moving heavy scaffold (9)</td>
<td>49</td>
<td>171</td>
<td>89</td>
<td>136</td>
<td>47</td>
<td>57.3</td>
</tr>
<tr>
<td>Moving heavy scaffold (10)</td>
<td>30</td>
<td>190</td>
<td>64</td>
<td>103</td>
<td>39</td>
<td>30.9</td>
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<tr>
<td>Moving heavy scaffold (11)</td>
<td>28</td>
<td>192</td>
<td>64</td>
<td>113</td>
<td>49</td>
<td>38.3</td>
</tr>
<tr>
<td>Regular work at heavy scaffold (12)</td>
<td>32</td>
<td>188</td>
<td>73</td>
<td>105</td>
<td>32</td>
<td>28.7</td>
</tr>
</tbody>
</table>

Table 4

Summary of the physiological assessment

<table>
<thead>
<tr>
<th></th>
<th>Average HRE</th>
<th>Average PHRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving light scaffold</td>
<td>52</td>
<td>50.7</td>
</tr>
<tr>
<td>Moving heavy scaffold</td>
<td>45</td>
<td>42.2</td>
</tr>
</tbody>
</table>

Table 5

Number of push–pull cycles per minute in the levers

<table>
<thead>
<tr>
<th></th>
<th>Cycles/min (light)</th>
<th>Cycles/min (heavy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raising</td>
<td>51</td>
<td>19</td>
</tr>
<tr>
<td>Lowering</td>
<td>62</td>
<td>23</td>
</tr>
</tbody>
</table>
light scaffolds’ lever is much higher than in the heavy scaffold (see Table 5). According to Silverstein et al. (1987), when the cycle time is below 30 s, the work might be considered repetitive.

Contrary to the data presented in Table 4, workers informally stated that they preferred to work on the light scaffolds, since they can be moved faster than the heavy ones (see Table 6 for the speed of each type). In fact, the higher speed of the light type was mostly due to the fewer number of levers to be handled. It is also worth noting that in all measurements, less time was required to raise than lower the scaffolds. This occurs because when the scaffold was raised, it was stopped by means of a mechanical device incorporated in the gears. However, when it was lowered, the worker spent both extra time and effort to stop the equipment manually.

4. Guidelines for improving working conditions in suspended scaffolds

Based on the data collected, some countermeasures for improving working conditions in suspended scaffolds could be detected. They are discussed below.

(a) Work station design: The heavy scaffolds could have their weight reduced by using metallic rather than thick wooden guardrails and planks. Also, the steel cables that suspended the scaffolds should be approximately the same length as the building height. This would reduce the scaffolds’ weight since those cables are fairly heavy (0.48 kg/m). Although the steel cables manufacturer supplied cables of standardized lengths (30, 45, 60 and 90 m), the contractors could require either a wider range of standard models or customization according to building height. The use of plastic covers on the gears (a NR-18 requirement that was not complied with in the studied sites) would additionally reduce the workload to move the scaffolds, since the covers prevent accumulation of mortar residuals on the gears. Another improvement concerning workstation design is the re-design of the gears for both types of scaffolds. The following design assumptions should be considered: both arms should be moved at the same time when operating the gears; the back should be kept straight or slightly bent when operating the gears. Body postures could also be improved once stands were provided to mortar boxes. This would prevent workers’ backs from bending to mix and take mortar out of the boxes.

The use of a roof over the scaffolds could be studied to minimize workers’ exposure to skin rash. Of course, this must not imply substantial increase in the equipment weight—in fact, this measure would be certainly more plausible to powered scaffolds. Moreover, lifelines should be placed around the roof parapet. This would allow workers to move more easily on the scaffolds planks.

(b) Work organization: At least two workers should operate the scaffold when moving it along the whole building height to start a new layer of coating. Even though this study has shown that the use of two operators still maintains physiological demand too high, this measure reduces the cycle time and, as a result, it reduces workers’ exposure to a hazardous environment.

(c) Product development: The architectural design should take into account the scaffolds positioning to coat building facades. In particular, there should be considered two NR-18 requirements: the maximum allowed length of scaffolds is 8.0 m, and the scaffold planks should not be off balance.

5. Conclusions

This study presented an ergonomic assessment of the operation of two types of suspended scaffolds (light and heavy) that are largely adopted by building contractors in Brazil. The results show that both types of scaffolds present an inadequate working environment. Moving the suspended scaffolds involves poor body postures, excessive physiological workload and high motion repetitiveness. This conclusion was disappointing for the contractor, since he expected that the light scaffold did not demand too much from the workers. In fact, prior to the study, the contractor intended to substitute all heavy scaffolds for the light ones.

Workers’ body postures were classified either in risk categories 3 and 4 (the most hazardous based on the OWAS method) in 37% and 48% of the working time when moving light and heavy scaffolds, respectively. These percentages are slightly lower (19% and 34%) when regular work from scaffolds is considered. The physiological demand was also found to be excessive. Heart rate elevations (HRE) were below the limit of 35 bpm only in two out of the 12 measurements and the percentage of the available heart rate range (PHRR) was below the limit of 33% only in three out of the 12 measurements. Also, the results pointed out that the physiological demand was not reduced below the limits adopted in this study when two workers operated the equipment together. Moreover, the
operation of the scaffolds’ levers was a highly repetitive task. The number of push–pull cycles per minute varied from 23 (lowering heavy scaffold) to 62 (lowering light scaffold) which leads to repetitive movements.

Also, both direct observation and workers’ reports indicated that unsafe acts were a commonplace. Unsafe acts, such as climbing over the gears to reach the ideal height to work, can be directly attributed to both safety planning, managerial control failures, and poor scaffold design. This combination pushed workers to carry out most of the violations observed.

Even though powered suspended scaffolds have become gradually more common in Brazil, only major contractors have adopted this equipment. For smaller contractors, it can be expected that manually operated suspended scaffolds will continue to be used in Brazilian construction sites for quite some time. Thus, it is necessary that both governments and construction companies take countermeasures to address the poor working conditions on scaffolds. The requirements of NR-18 regulation concerning the design of suspended scaffolds should be reviewed. Structural safety should not lead to overweight, which results in an unacceptable workload for operators. Moreover, ergonomic requirements could be proposed for designing gears and levers, so both awkward postures and physiological demands are minimized. Management failures that generate additional workload and risk to the scaffolds’ operators should be tackled by safety management techniques. For example, as detected in this study, product design should consider the feasibility of installing scaffolds around the whole building facade.

References


