Ergonomic measures in construction work: enhancing evidence-based implementation
Visser, S.

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CHAPTER 2.1

EVALUATION OF TWO WORKING METHODS FOR SCREED FLOOR LAYERS ON MUSCULOSKELETAL COMPLAINTS, WORK DEMANDS AND WORKLOAD

Visser S, van der Molen HF, Kuijer PPFM, van Holland BJ, Frings-Dresen MHW
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ABSTRACT

Screed floors are bound by sand–cement (SF) or by anhydrite (AF). Sand–cement floors are levelled manually and anhydrite floors are self-levelling and therefore differences in work demands and prevalences of musculoskeletal complaints might occur. The objective was to assess among SF layers and AF layers (1) the prevalence of musculoskeletal complaints and (2) the physical work demands, energetic workload, perceived workload and discomfort.

A questionnaire survey and an observational field study were performed. Compared with AF layers (n=35), SF layers (n=203) had higher, however, not statistically significant different, prevalences of neck (20% vs. 7%), shoulder (27% vs. 13%), low back (39% vs. 26%) and ankles/feet (9% vs. 0%) complaints. Sand–cement-bound screed floor layers (n=18) bent and kneeled significantly longer (∆77 min and ∆94 min; respectively), whereas AF layers (n=18) stood significantly longer (∆60 min). The work demands of SF layers exceeded exposure criteria for low back and knee complaints and therefore new working measures should be developed and implemented.
INTRODUCTION

In the Netherlands, 38% of construction workers reported complaints involving the low back and the lower limbs. Work-related low back complaints are associated with manual material handling and bent or twisted trunk postures. Kneeling and squatting are risk factors for work-related knee complaints. Among floor layers, bending and kneeling frequently occur. According to Burdorf et al., floor layers spent 33% of the workday in a kneeling working posture and 20% of the workday in a trunk flexion of more than 40°. Jensen et al. reported that floor layers spend 41% of the workday in knee-straining working postures. Therefore, floor layers are at increased risk for low back and knee complaints.

Floor laying is covered by a variety of construction jobs. Construction workers who install vinyl-, linoleum-, terrazzo-, carpet- and screed floors can all be referred to as floor layers. This study focuses upon floor layers who install screed floors. A screed floor can be bound by sand–cement (SF) or by anhydrite (AF). In general, both types of screed floor are laid by a team of three floor layers. Because of the mixture, a SF must be levelled manually. During levelling, floor layers work in a kneeling and bent trunk postures (figure 1a). Anhydrite floors are self-levelling, allowing floor layers to work in a more upright trunk posture (figure 1b). Jensen and Friche have shown a reduction in self-reported knee complaints by vinyl floor layers when the work was done in a more upright trunk posture rather than while kneeling.

The prevalence of musculoskeletal complaints and the physical work demands among AF layers are unclear. In addition, it is unknown whether these complaints and work demands are different compared with SF layers. The different work techniques required for the installation of SF and AF may also lead to differences in the energetic workload, perceived workload and perceived discomfort between SF layers and AF layers.

This led us to ask the following two research questions: 1) Does the prevalence of musculoskeletal complaints differ between SF layers and AF layers? and 2) Does the exposure to physical work demands and the energetic and experienced workload differ between SF layers and AF layers? Although the physical work demands might differ between both groups, both groups still might be at risk for work-related musculoskeletal complaints. Therefore, a third question was defined: 3) Does the physical work demands for SF layers and AF layers exceed the exposure criteria for work-related musculoskeletal complaints?

METHODS

To answer the first question, a cross-sectional, questionnaire-based survey was performed. The second question was answered by means of an observational field study. To answer the third question, outcomes of the observational field study were compared with exposure criteria for the assessment of work-related musculoskeletal complaints.
Questionnaire

Participants and survey procedures
All floor layers (n=779) known to the National Board of Employers in the Finishing Sector, regardless of the type of floor they laid, were asked to participate in this questionnaire study. Addresses of the employees were obtained by the aforementioned National Board. The employees received a letter from the National Board that included the purpose of the study and the questionnaire. After two weeks, a reminder letter and another copy of the questionnaire were sent. The questionnaire could be returned up to one month after receiving the reminder.

Content of the questionnaire
The six-month prevalence of musculoskeletal complaints was assessed with the Dutch Musculoskeletal Questionnaire. Answer categories were ‘no, never’, ‘yes, sometimes’, ‘yes, regular’ and ‘yes, sustained’. Respondents answering the questions with the categories ‘no, never’ or ‘yes, sometimes’ were defined as having no complaints. The other two categories were defined as having musculoskeletal complaints.

Statistical analyses
Differences in the proportion of SF layers and AF layers with musculoskeletal complaints were tested using Chi-squared tests. All statistical analyses were performed with the SPSS.
Evaluation of two working methods for screed floor layers

v.16.0 statistical package (SPSS, Inc., Chicago, IL, USA). The statistical significance was defined as p<0.05.

Observational study

Participants and procedure for evaluating physical work demands, workload and perceived discomfort

Six companies that laid SF and/or AF voluntarily participated following a request from the National Board of Employers in the Finishing Sector. These six companies selected six teams of three SF layers (n=18) and six teams of three AF layers (n=18) who only laid SF or AF, respectively. To participate in the study, each participant had to have at least six months working experience as a floor layer. The physical work demands, energetic workload, perceived workload and perceived discomfort of the 18 SF layers and 18 AF layers during an entire workday were evaluated in an observational field study. All floor layers were informed about the purpose and the assessment methods of the study and agreed to participate by signing an informed consent form. Bootstrap revealed that all day observations of 18 SF layers and 18 AF layers resulted in accurate measurements of the observed activities with an average standard error of the mean (SEM) of 4% for SF layers and 7% for AF layers.

Observation strategy

Physical work demands

Observations of physical work demands were performed by means of a real-time hierarchical task analysis with the Task Recording and Analysis on Computer system. During the observations, each floor layer was observed by one observer, and three observers followed a team of three floor layers during a typical workday. The three observers assessed the tasks, the activities performed during these tasks, the objects being handled and the body posture of the floor layers during the entire workday. The duration of the following variables and categories within variables were observed on a real-time basis: task (preparation, spreading the mixture, measuring height of the screed floor, levelling and finishing, tidying up, cleaning, consultation, micro pauses, break, other unspecified tasks); activities (walking, standing, sitting, kneeling, squatting, climbing, shovelling, pushing/pulling, lifting/carrying, repeated arm motions); object (tripod, small work tools (such as a plastering trowel), floating machine, cement bag, (mortar) hose, landmark); trunk flexion (less than or equal to 40°, more than 40°) and arm elevation (defined as hands higher than shoulder height).

To reduce errors caused by unclear observational criteria, all three observers were trained in real-time observations with the help of videos of floor layers. When differences between two classes (e.g. arm elevation) occurred, these differences were discussed and agreed upon. To test the variation between the three observers, each observer assessed the same segment of a video (16 min long for SF layers and 10 min for AF layers) that was not used to train the observers. The calculated interclass coefficient between the observers...
ranged between 0.8 and 1.0 for the most important tasks, activities and body postures. This interclass coefficient was considered adequate for workplace observations.

**Energetic workload.**
To determine the energetic workload, the participants wore a Polar RS800™ (Kempele, Finland) heart rate monitoring device. Their heart rates were continuously measured and registered every 15 s during the entire workday. Their energetic workloads were expressed as percentages of the heart rate reserve (%HRR), which were calculated by the formula of Karvonen et al.\(^\text{17}\): 
\[
\text{%HRR} = \left( \frac{\text{HR}_{\text{avg}} - \text{HR}_{\text{rest}}}{\text{HR}_{\text{max}} - \text{HR}_{\text{rest}}} \right) \times 100\%
\]
\(\text{HR}_{\text{avg}}\) was defined as the average heart rate during the workday, \(\text{HR}_{\text{rest}}\) was the lowest heart rate during a workday during a 5-min period and \(\text{HR}_{\text{max}}\) was the maximal heart rate calculated by the formula of Gellish et al.\(^\text{18}\): 
\[
\text{HR}_{\text{max}} = 207 - (0.7 \times \text{age})
\]

**Perceived workload.**
To assess the perceived workload, a visual analogue scale (VAS) of 100 mm\(^\text{19}\) was used. The VAS ranged from 0 (‘not heavy at all’) to 100 mm (‘extremely heavy’). Each participant was asked to rate the perceived workload twice during the workday: after 3 h of work and at the end of the workday.

**Perceived local discomfort.**
The participants were asked three times during a workday to rate their perceived local discomfort in the neck, lower back, upper extremities (shoulders, elbows, wrists and hand/fingers) and lower extremities (hips, knees, ankles) with a VAS of 100 mm. Discomfort was defined as local aches, stiffness and/or fatigue or pain, and was assessed at the start of a workday, after 3 h of work and at the end of a workday. The VAS ranged from 0 (‘no perceived discomfort at all’) to 100 mm (‘worst perceived discomfort’).

**Comparison with exposure criteria for work-related musculoskeletal complaints.**
The exposure to physical work demands was compared with exposure criteria for work-related musculoskeletal disorders.\(^\text{15}\) Exposure criteria for nonspecific low back pain,\(^\text{20}\) osteoarthritis of the knee,\(^\text{21}\) injury of the meniscus,\(^\text{22}\) plantar fasciitis\(^\text{23}\) and for specific and nonspecific upper limb complaints, such as cervicobrachial syndrome, rotator cuff syndrome and flexor/extensor tendinitis\(^\text{24}\) were used. An overview of the used exposure criteria is given in table 3. The exposure criteria for the energetic workload were those defined by Wu and Wang.\(^\text{25}\) For a workday of 8 h, the energetic workload may not exceed a %HRR of 25%. The mean duration of kneeling, standing, trunk flexion, lifting/carrying, arm elevation and repeated arm movements on group level were calculated and compared with relevant exposure criteria. In addition to the group-level comparisons, the number of individual SF layers or AF layers who exceeded any of the specified exposure criteria was also described.
Evaluation of two working methods for screed floor layers

Statistical analyses
For each floor layer, the total duration (in min) of the observed variables during a workday was calculated. The mean values of the outcome measures were calculated for the 18 SF layers and 18 AF layers. To evaluate whether there was a difference between the physical work demands of SF layers and AF layers, the mean durations of the tasks, activities and body postures were compared between the two groups. To correct for the dependency of team, a Linear Mixed Model was used to assess the differences among SF layers and AF layers. Differences between the energetic workloads of the two types of floor layers were tested using an Independent Samples t-test. Differences in perceived workload and perceived discomfort of the body regions were tested using Generalised Estimating Equations. All statistical analyses were performed with the SPSS v.16.0 statistical package (SPSS, Inc.). The statistical significance was defined as p<0.05.

RESULTS

Questionnaire
Participants
A total of 409 of the 779 floor layers returned the questionnaire (response rate of 53%). Of these 409 floor layers, 203 (50%) were SF layers and 35 (9%) were AF layers. The other 171 floor layers (41%) laid both types of screed floors or other types of floors and were therefore excluded from the analyses. The mean (SD) values of age, body height, body weight and seniority as a screed floor layer of SF layers and AF layers were 41 (12) vs. 42 (13) years, 181 (7) vs. 181 (7) cm, 86 (13) vs. 89 (16) kg and 17 (12) vs. 10 (7) years, respectively. With the exception of seniority (p=0.000), no significant differences between the two groups of workers in terms of these characteristics were found.

Musculoskeletal complaints
Table 1 shows the six-month prevalence of musculoskeletal complaints of the neck, shoulders, upper back, lower back, elbows, wrists/hands, hips/thighs, knees and ankles/feet for SF layers and AF layers in this study. Low back complaints were common, with 39% of the SF layers and 26% of the AF layers reporting low back complaints (p=0.160). Besides complaints of the low back, large differences between SF layers and AF layers were found for complaints of the neck (20% vs. 7%), the shoulders (27% vs. 13%) and the ankles/feet (9% vs. 0%). These differences were not statistically significant.

Observational study
Participants
The mean and SD values of the age, height, weight and seniority as a screed floor layer of SF layers participating in the field study were 43 (12) years, 180 (6) cm, 86 (12) kg and 19 (14), respectively. The mean (SD) age, height, weight and seniority as a screed floor layer of AF
layers participating in the field study were 41 (10) years, 181 (6) cm, 88 (16) kg and 16 (12) years. There were no significant differences between the two groups in terms of these characteristics.

**Physical work demands**

Table 2 shows the results of the analysis of the duration of tasks, activities and body postures. The duration of a workday on the worksite was 5 h 50 min (min–max: 4 h 54 min–6 h 40 min) for SF layers and 6 h 19 min (min–max: 4 h 19 min–8 h 3 min) for AF layers \((p=0.367)\). Most of the time, both types of floor layers were working in a standing position (SF layers: 146 (SD 59) min and AF layers: 206 (SD 81) min). However, the standing duration was 1 h shorter for SF layers compared with AF layers \((p=0.027)\). The mean duration of kneeling during a workday was longer for SF layers (97 (SD 58) min) compared with AF layers (3 (SD 5) min; \(p=0.000\)). Additionally, SF layers worked for 98 (SD 41) min in a bent trunk posture compared with 21 (SD 16) min for AF layers \((p=0.000)\).

**Workload**

The %HRR was higher for SF layers compared with AF layers: 28% (95% confidence interval (95% CI): 24.5–32) vs. 23% (95% CI: 18.5–27.3), respectively. This difference was not statistically significant \((p=0.056)\). Additionally, no significant difference between SF layers and AF layers was found in perceived workload after 3 h of work (24 (SD 22) vs. 32 (SD 16), respectively; \(p=0.239\)) and at the end of a workday (23 (SD 23) vs. 31 (SD 22), respectively; \(p=0.343\)).

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**Table 1** Six-month prevalence of musculoskeletal complaints for sand-cement-bound screed floor layers (SF layers) and anhydrite-bound screed floor layers (AF layers) and the \(p\)-values of the difference in prevalence between SF layers and AF layers.

<table>
<thead>
<tr>
<th>Body region</th>
<th>SF layers</th>
<th>AF layers</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Prevalence (%)</td>
<td>n</td>
</tr>
<tr>
<td>Neck</td>
<td>38/186</td>
<td>20%</td>
<td>2/29</td>
</tr>
<tr>
<td>Shoulders</td>
<td>50/187</td>
<td>27%</td>
<td>4/31</td>
</tr>
<tr>
<td>Upper back</td>
<td>26/184</td>
<td>14%</td>
<td>3/31</td>
</tr>
<tr>
<td>Lower back</td>
<td>74/190</td>
<td>39%</td>
<td>8/31</td>
</tr>
<tr>
<td>Elbows</td>
<td>27/184</td>
<td>15%</td>
<td>3/32</td>
</tr>
<tr>
<td>Wrists/hands</td>
<td>33/187</td>
<td>18%</td>
<td>4/31</td>
</tr>
<tr>
<td>Hip/thighs</td>
<td>20/181</td>
<td>11%</td>
<td>2/32</td>
</tr>
<tr>
<td>Knees</td>
<td>38/186</td>
<td>20%</td>
<td>6/33</td>
</tr>
<tr>
<td>Ankles/feet</td>
<td>17/183</td>
<td>9%</td>
<td>0/30</td>
</tr>
</tbody>
</table>
Evaluation of two working methods for screed floor layers

Perceived discomfort
No difference was found between the two types of floor layers in perceived discomfort at the start of a workday. Additionally, there was no difference between the two groups in the increase or decrease of the perceived discomfort during a workday. Perceived discomfort of the low back was the most common area of discomfort for both groups of floor layers: the mean (SD) perceived discomfort on a scale from 0 to 100 was 14 (20) for SF layers and 17 (28) for AF layers (p=0.767) at the beginning of a workday, 10 (18) vs. 18 (28), respectively (p=0.313), after three hours of working and 11 (17) vs. 21 (29), respectively (p=0.211), at the end of a workday.

Table 2  Mean (SD) (in min) durations of the tasks, activities and body postures for sand-cement-bound screed floor layers (SF layers; n=18) and anhydrite-bound screed floor layers (AF layers; n=18).

<table>
<thead>
<tr>
<th>Outcome measures</th>
<th>SF layers</th>
<th>AF layers</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tasks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparation</td>
<td>59 (25)</td>
<td>96 (28)</td>
<td>0.002</td>
</tr>
<tr>
<td>Spreading</td>
<td>66 (63)</td>
<td>65 (98)</td>
<td>0.972</td>
</tr>
<tr>
<td>Measuring height</td>
<td>8 (9)</td>
<td>48 (31)</td>
<td>0.042</td>
</tr>
<tr>
<td>Finishing</td>
<td>114 (63)</td>
<td>33 (55)</td>
<td>0.000</td>
</tr>
<tr>
<td>Tidying up</td>
<td>14 (4)</td>
<td>24 (12)</td>
<td>0.012</td>
</tr>
<tr>
<td>Cleaning</td>
<td>12 (11)</td>
<td>14 (12)</td>
<td>0.463</td>
</tr>
<tr>
<td>Consultation</td>
<td>5 (6)</td>
<td>3 (7)</td>
<td>0.443</td>
</tr>
<tr>
<td>Micro pauses</td>
<td>18 (20)</td>
<td>30 (23)</td>
<td>0.159</td>
</tr>
<tr>
<td>Break</td>
<td>47 (16)</td>
<td>52 (19)</td>
<td>0.668</td>
</tr>
<tr>
<td>Other</td>
<td>7 (6)</td>
<td>14 (25)</td>
<td>0.466</td>
</tr>
<tr>
<td><strong>Activities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>53 (19)</td>
<td>99 (61)</td>
<td>0.003</td>
</tr>
<tr>
<td>Standing</td>
<td>146 (59)</td>
<td>206 (81)</td>
<td>0.027</td>
</tr>
<tr>
<td>Sitting</td>
<td>1 (1)</td>
<td>3 (5)</td>
<td>0.147</td>
</tr>
<tr>
<td>Kneeling</td>
<td>97 (58)</td>
<td>3 (5)</td>
<td>0.000</td>
</tr>
<tr>
<td>Squatting</td>
<td>1 (1)</td>
<td>2 (4)</td>
<td>0.172</td>
</tr>
<tr>
<td>Climbing</td>
<td>2 (3)</td>
<td>5 (4)</td>
<td>0.095</td>
</tr>
<tr>
<td>Lifting/carrying</td>
<td>9 (7)</td>
<td>74 (98)</td>
<td>0.007</td>
</tr>
<tr>
<td>Pushing/pulling</td>
<td>13 (19)</td>
<td>4 (5)</td>
<td>0.076</td>
</tr>
<tr>
<td>Repeated arm motions</td>
<td>107 (37)</td>
<td>31 (50)</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Body postures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk flexion</td>
<td>98 (41)</td>
<td>21 (16)</td>
<td>0.000</td>
</tr>
<tr>
<td>Arm elevation</td>
<td>35 (23)</td>
<td>1 (3)</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Perceived discomfort
No difference was found between the two types of floor layers in perceived discomfort at the start of a workday. Additionally, there was no difference between the two groups in the increase or decrease of the perceived discomfort during a workday. Perceived discomfort of the low back was the most common area of discomfort for both groups of floor layers: the mean (SD) perceived discomfort on a scale from 0 to 100 was 14 (20) for SF layers and 17 (28) for AF layers (p=0.767) at the beginning of a workday, 10 (18) vs. 18 (28), respectively (p=0.313), after three hours of working and 11 (17) vs. 21 (29), respectively (p=0.211), at the end of a workday.
CHAPTER 2.1

Comparison with exposure criteria
The mean duration of trunk flexion and of kneeling of SF layers exceeded the exposure criteria for the duration of trunk flexion and kneeling (table 3), by 68 and 37 min, respectively. Among the SF layers, 14 (78%) exceeded the criteria for kneeling and 16 (89%) exceeded the criteria for trunk flexion. The mean duration of activities and body postures of AF layers did not exceed the exposure criteria. However, four (22%) AF layers exceeded the criteria for trunk flexion and six (33%) exceeded the criteria for the duration of standing. The criterion for the energetic workload of Wu and Wang was exceeded on average by SF layers. On an individual level, 11 (65%) SF layers and 3 (19%) AF layers exceeded the criteria for the energetic workload.

DISCUSSION
The prevalence of low back, neck, shoulders and ankles/feet complaints were higher for SF layers compared with AF layers, although the results were not statistically significant. Compared to AF layers, SF layers spent significantly more time working in a bent trunk and kneeling working posture. The duration of bending and kneeling of SF layers exceeded previously established exposure criteria of 30 min more than 40° for trunk flexion and 1 h for kneeling or squatting, respectively per workday. The energetic workload was higher for SF layers compared with AF layers, although the difference between SF layers and AF layers was not statistically significant. The perceived workload and perceived discomfort did not differ statistically between SF layers and AF layers during a workday.

Methodological aspects
The response rate for the questionnaire of all floor layers was 53%, and in line with earlier questionnaire studies among construction workers in the Netherlands. The number of respondents of AF layers (n=35) was much smaller than the number of respondents of SF layers (n=203), possibly resulting in a lack of power for the questionnaire study. The National Board of Employers in the Finishing Sector cannot distinguish between SF layers and AF layers in their dataset. Therefore, the exact number of AF layers and SF layers working in the Netherlands is unknown and a comparison between the response rate for each type of floor layers could not be made.

As mentioned in the method, estimates of the accuracy of the assessments of the physical work demands were performed with a bootstrap method. The SEM of the mean duration of activities and body postures was between 0 and 3 min (2–11%) for SF layers and between 0 and 5 min (2–14%) for AF layers. For both SF layers and AF layers, most of the low SEMs (3% or less) were found for activities and body postures with an average duration of more than 10 min during a workday. Activities and body postures with an average duration of less than 10 min had SEMs ranging from 6 to 14%. In addition to the
SEM, the duration of activities and body postures was corrected for the team in which the floor layers were working. Due to this correction and the small SEM, the results of the work demands are herewith considered to be the representative of Dutch screed floor layers.

Table 3  Comparison of the physical work demands and physical workload of sand-cement-bound screed floor layers (SF layers) and anhydrite-bound screed floor layers (AF layers) based on exposure criteria for work-related musculoskeletal complaints and energetic workload. Besides the mean duration of the criteria variables, the number of individual floor layers exceeding the criteria is given.

<table>
<thead>
<tr>
<th>Criteria variable</th>
<th>SF layers</th>
<th>AF layers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean of criteria variable</td>
<td>Numbers of individuals exceeding criteria</td>
</tr>
<tr>
<td><strong>Low back</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk flexion &gt;40° &gt;30 min during a workday</td>
<td>98 min *</td>
<td>16/18</td>
</tr>
<tr>
<td>Lifting/carrying a weight &gt;15 kg for &gt;10% of a workday</td>
<td>3%</td>
<td>0/18</td>
</tr>
<tr>
<td>&gt;5 kg 2x per min lifting for 2 h per workday</td>
<td>29 min</td>
<td>0/18</td>
</tr>
<tr>
<td><strong>Upper extremities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hands above shoulder height &gt;2 h per workday</td>
<td>35 min</td>
<td>0/18</td>
</tr>
<tr>
<td>Repetitive movements (2-4 times/min) &gt;4 h per workday</td>
<td>1 h 47 min</td>
<td>0/18</td>
</tr>
<tr>
<td>Effort of 40 N &gt;2 h per workday</td>
<td>13 min</td>
<td>0/18</td>
</tr>
<tr>
<td>Arm vibrations &gt;1 h per workday</td>
<td>11 min</td>
<td>0/18</td>
</tr>
<tr>
<td><strong>Lower extremities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kneeling or squatting &gt;1 h per workday</td>
<td>97 min *</td>
<td>14/18</td>
</tr>
<tr>
<td>Standing &gt;4 h per workday</td>
<td>2 h 26 min</td>
<td>1/18</td>
</tr>
<tr>
<td><strong>Energetic workload</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% (8-h workday)</td>
<td>28%</td>
<td>11/17</td>
</tr>
</tbody>
</table>

Note: *Mean duration of the variable exceeded the exposure criteria.
The results of the physical work demands of SF layers, like standing for 58% and kneeling or squatting for 28% of the workday, have also been confirmed by previous research. Burdorf et al.\textsuperscript{10} found that SF layers worked 60% of a workday in an upright trunk posture and 33% in a kneeling or squatting position when the screed mixture was transported mechanically to the worksite: the same work method as observed in the present study.

**Work demands, work-related health complaints and working methods**

Compared with AF layers, SF layers worked significantly longer in a kneeling posture or bent trunk posture and spent less time standing. The duration of kneeling and bending for SF layers exceeded previously established exposure criteria for work-related musculoskeletal complaints of the low back and the knees. The exposure criteria for low back complaints\textsuperscript{20} and knee complaints\textsuperscript{21,22} are in line with more recent studies.\textsuperscript{2-5,11,12} Exceeding these criteria is associated with an increased risk of work-related musculoskeletal complaints and should therefore be prevented in daily work practice. It was therefore expected that the prevalence of musculoskeletal complaints of the knees and the low back would be higher for SF layers compared with AF layers.

The expectation is confirmed by the results of the present cross-sectional questionnaire, more SF layers had musculoskeletal complaints compared with AF layers. However, due to a lack of power as a result of the small number of respondents of especially AF layers on the questionnaire study, no statistical differences in musculoskeletal complaints were found. The prevalence of low back complaints of the present study are comparable to the six-months prevalence of floor layers found by Burdorf et al.,\textsuperscript{10} 34%. In addition, the prevalence of musculoskeletal complaints in the present study is similar to the prevalence of musculoskeletal complaints of the general Dutch populations.\textsuperscript{28}

A previous study of Jensen et al.\textsuperscript{8} found a 12-month prevalence of 65% for knee complaints among floor layers, which is more than three times higher compared with the prevalence of 20–18% found in the present study. The difference might be partly explained by the time spent in knee-straining working postures. Floor layers worked for 41–56% of their workday in knee-straining working postures,\textsuperscript{8,9} while the percentage of time working in knee-straining postures was on average 28% for SF layers in the present study. Another explanation might be the definition of complaints. In this study, the more severe answer categories (regular or sustained) were defined as having musculoskeletal complaints. With the addition of the answer category ‘sometimes’ as having musculoskeletal complaints, the six-month prevalence of low back and knee complaints would be 74 and 49%, respectively, in the present study.

The seniority of both SF layers and AF layers was below 20 years. An odds ratio of 0.7 was found for radiographic tibiofemoral knee osteoarthritis between floor layers and graphic designers with a seniority of <20 years.\textsuperscript{29} The odds ratio increased to 4.82 for a seniority of >30 years. As a result, prolonged high exposure towards knee straining
activities could result in future knee complaints. The low seniority and low prevalence of complaints in the present study might be due to the healthy worker survivor effect. As a result of musculoskeletal complaints (e.g. low back or knee problems), affected construction workers have a disproportionately high rate of occupational changes or early retirement due to permanent disability. It is expected that the average age of screed floor layers will increase until 2025, resulting in higher seniority of the screed floor layers and an increased risk of knee complaints. To reduce the risk of these work-related musculoskeletal complaints, an adaption in working methods and working techniques is required to reduce the duration of bending and kneeling.

The mean %HRR of SF layers and AF layers was 28 and 23%, respectively, and was within the range of the energetic workloads of masonry workers (21–28%) and lower compared with the range of gypsum brick layers (29–33%). Sand–cement floor layers exceeded the criterion of 25% HRR, established for an 8-h workday. However, the duration of an average workday in the present study was shorter for both SF layers and AF layers. The estimation of an acceptable duration of an entire workday according to Wu and Wang for SF layers is approximately 7 h. This is longer compared with their actual working time. Therefore, exceeding the criteria for energetic workload seems not a risk for SF layers from a healthy perspective and does not require intervention.

The more standing working postures of AF layers is more favourable in comparison with the bent and kneeling working postures of SF layers, with respect to the risk of work-related musculoskeletal complaints. However, some remarks could be made of the static working method of AF layers since six out of 18 AF layers exceeded the exposure criteria for standing. In addition, four out of 18 AF layers exceeded the exposure criteria for working in a bent trunk posture. However, the duration of standing and bending was on average lower compared with the exposure criteria.

This present study has only focussed upon musculoskeletal complaints. It is known that auditory, respiratory, dermal and stress complaints frequently occur among construction workers too. Since sand–cement-bound screed floors differs with respect to chemical substances, working method and working tools from anhydrite-bound screed floors, differences in auditory, respiratory, dermal and stress complaints could occur between SF layers and AF layers. These complaints and the exposure towards factors increasing the risk for developing these type of complaints should be taken into account besides the musculoskeletal complaints and physical work demands when a comparison of working method and workplace prevention between SF layers and AF layers is made.

**Preventive ergonomic measures**

Because of the differences in technical flooring characteristics between the two types of screed floors, such as pressure resistance and price, a sand–cement-bound screed floor is not easily replaced by an anhydrite-bound screed floor. An anhydrite-bound screed floor is advisable to reduce the risk of low back and knee complaints. Therefore, the reduction
of time spent in a bent trunk postures and kneeling for SF layers must be preferably accomplished by ergonomic measures. Bending and kneeling mainly occur during levelling of the sand–cement-bound screed floor. In collaboration with the Dutch Labour Inspectorate, the Dutch Employers Organisation for the Finishing Sector has agreed to develop and evaluate measures to perform the levelling of a sand–cement-bound screed floor in an upright working posture. This should result in less time spent in bent trunk postures or kneeling by the workers.

**CONCLUSION**

Absolute differences in prevalence of neck, shoulder, low back and ankles/feet complaints were higher among SF layers in comparison with AF layers, although the results were not statistically different. The exposure for kneeling and bent body postures was significantly larger for SF layers compared with AF layers and exceeded exposure criteria. Therefore, SF layers are at higher risk for work-related musculoskeletal complaints of the low back and the knees. The energetic workload was higher for SF layers compared with AF layers, although the difference between SF layers and AF layers was not statistically significant. The duration of the workdays of both SF layers and AF layers did not exceed exposure criteria. To reduce the risk for SF layers for work-related complaints, new working measures should be developed and implemented.
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