Job-specific workers’ health surveillance for construction workers
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Chapter 2.

Occupational demands and health effects for bricklayers and construction supervisors: A systematic review.

Boschman JS, van der Molen HF, Sluiter JK, Frings-Dresen MHW.

Abstract

Background:
Knowledge was gathered on occupational demands and health effects of two occupations in the construction industry, bricklayers and supervisors, in order to design a job-specific workers’ health surveillance (WHS) for construction workers.

Methods:
We systematically searched MEDLINE, EMBASE, PsycINFO, HSELINE, NIOSHTIC-2 and Picarta up to December 2008.

Results:
A total of 60 articles were included. Evidence was found for the following demands for bricklayers: energetic load (exceeding 25% heart rate reserve), load on the lower back (exceeding the NIOSH-threshold value of 3.4 kN), repetitive force exertions of the upper extremities, frequent bending with trunk flexion exceeding 60 degrees and working with the arms more than 60 degrees elevated. Environmental demands include: dust and quartz exposure (exceeding the limit values of 3.0 mg/m³ and 0.05 mg/m³ respectively), vibration and noise (exceeding the limit value of 80 dBA). Bricklayers are at increased risk of lung cancer, low back pain, complaints of arms and legs and getting injuries. Among construction supervisors are walking and standing common physically demanding activities. Psychosocial demands with evidence for supervisors were mental demands, workload, time pressure, working long hours and social-organizational factors. Supervisors are at increased risk of lung cancer and injuries.

Conclusions:
For bricklayers evidence was found for physical demands and risk on low back pain and complaints of arms and legs, for construction supervisors on psychosocial demands. Both occupations are at increased risk of lung cancer and injuries. Job-specific demands and health effects should be incorporated in WHS for construction workers.
Introduction

Work in the construction industry is associated with health and safety risks. Over the years, research has focused upon safety problems\textsuperscript{1-4} and less attention has been paid to other health-related issues.\textsuperscript{5} Nevertheless, occupational injuries and diseases in construction workers result in lost productivity, disability and even mortality\textsuperscript{6,7}, creating a financial burden for this industry.\textsuperscript{8}

Signals of adverse health effects could be detected in an early stage by offering a periodic workers’ health surveillance (WHS) program to individual employees. WHS is a generic term that covers procedures and assessments of workers’ health and work capacity in order to detect and identify any signals of change. In a WHS program, both primary and secondary preventive purposes play a role. Primary prevention aims at avoiding the development of an occupational disease, whilst secondary prevention aims at early detection of disease signs. Intervention measures can be carried out when the health status or work capacity of the worker changes over time to prevent the worker from suffering from reduced functioning.

WHS programs in the construction industry are widely used and in several countries prescribed by law. However, the scientific basis for their content or effectiveness was not well documented a decade ago.\textsuperscript{7,9} Up to now, the effectiveness of WHS in general is still unknown. Although modern health care is becoming more and more evidence-based, occupational health care lags behind these developments.\textsuperscript{10} The Dutch Society of Occupational Medicine (NVAB) has proposed a goal-oriented approach regarding the development of WHS programs based on the guidelines provided by the International Labour Office.\textsuperscript{11,12} One of the key elements in this approach is the need to specify the goals of the WHS program. The implementation of the WHS program — for example, assessments, tests and investigations — must be based on these goals. In other words, a careful method in which conscious choices are made must be in place before a WHS program is put into practice. As part of this method, an occupation-specific approach to developing a WHS program has been chosen.\textsuperscript{13} After all, due to the diversity of occupations in the construction industry, not all workers are exposed to the same hazards, and not all occupations require the same physical capacity. Therefore, it is appropriate to tailor the WHS to the specific demands of each occupation.\textsuperscript{14,15}

In order to construct a WHS, a full step-by-step approach for both demands and health effects must be completed, as both may give rise to the content of a WHS. For the demands the following steps could be undertaken in order to decide whether or not the demand should be included in the WHS\textsuperscript{16}: determine the exposure in terms of duration, frequency and intensity as described in the literature, determine whether the exposure is (possibly) related to the risk of health complaints for the worker and whether the exposure exceeds regulatory or professional guidelines. For health effects it should be determined whether
there is epidemiological evidence that the workers are at increased risk or whether the health effect is more prevalent for the occupation at hand than for the general, working population. Demands or health effects influencing the safety of the worker or others should also be considered in the development of a WHS.

When developing a WHS for construction workers it must be taken into account that the construction industry consists of both physically and mentally demanding occupations. Therefore, we have chosen two occupations which comprise a large part of the construction industry and are representative for a more physically or more mentally demanding occupation: bricklayers and construction supervisors, respectively.

By doing this systematic literature review we aim at providing a solid basis for an occupation-specific and evidence-based WHS for two distinct occupations in the construction industry. The present systematic literature review addresses the following questions:
1) What are the occupational demands for bricklayers and construction supervisors?
2) What are the health effects associated with the occupations of bricklayer and construction supervisor?

**Methods**

**Population**

This systematic literature review aimed at identifying occupational exposures or demands and health effects for:
1) Bricklayers engaged in building and renovating houses, offices and industrial complexes using bricks, blocks and mortar. Bricklayers handling blocks are also referred to as blocklayers;
2) Construction supervisors or other occupations in the construction industry with a focus on daily project management, like ‘foremen’ and ‘site supervisors’.

**Search strategy**

In order to search the literature systematically and in an unbiased manner, the search strategy was based on the model proposed by Van Dormolen et al.\(^17\) (Figure 1). In this model, the relationship between demands, internal load and health effects was presented: demands are the characteristics of the job’s content, conditions, relations and conditions of employment that evoke a response. These responses represent the internal load and are the indicators of exposure during work or temporary effects (lasting a few hours), like heart rate, muscle activity or a rise in hormone concentrations. Analogous terms often used are external exposures (for demands) and internal exposures or reactivity measures (for internal load). In addition to temporary effects, the work could also induce more permanent health
effects. These health effects may be positive or negative and are sometimes reversible (e.g., low back pain), but may also be irreversible (e.g., lung cancer due to carcinogenic exposure).

Two systematic literature searches were performed on 1) occupational demands and 2) health effects associated with the occupations of bricklayer or construction supervisor. The systematic literature searches were performed up to December 2008 to locate studies in electronic databases, including Medline using the Pubmed interface (1965-present), Embase (1980-present) and Psycinfo (1806-present) via Ovid. The searches were not restricted by language or publication status. Grey literature was identified by searching the electronic databases HSE-line, NIOSHTIC-2 and Picarta. Google was searched on December 17th 2008.

According to the ‘snowball method’, the references of each report or article found by the electronic search were searched manually for more articles on exposures or health effects meeting the inclusion criteria. One of the reviewers provided three relevant sources of information, which were added to the selection.

**Inclusion and exclusion criteria**

Study selection was based on the following criteria: 1) the article is written in Dutch, English or German and was published in the period 1993-2008, 2) the study concerns bricklayers or supervisors in the construction industry or tasks performed by bricklayers or supervisors in the construction industry, 3) bricklayers or construction supervisors represent more
than 50% of the population to which the outcome applies, and 4) exposures or health effects are measured. In order to select relevant exposure data, the inclusion criteria were supplemented with: 5) the study or a part of the study has an observational design. For the search on health effects case studies were excluded. In general, studies concerning bricklayers or construction supervisors with non-Western working styles (like carrying bricks on the head) were excluded.

Title and abstract of all identified studies were read. If no abstract was available, or if, based on the abstract, it was unclear whether a study should enter this systematic review, the whole article was retrieved and read.

**Data extraction and management**

JB extracted the following data from the articles on occupational exposures: task, activity or factor representing a demand, measurement method, participants (number, age, country) and setting (if applicable), outcome measure used, and exposure in terms of duration, frequency and intensity or internal load. In case of an intervention study, data before as well as after the intervention were extracted. When data on exposures were only graphically represented, quantity was estimated from the figure when possible. In addition, the exposures or load measures were grouped into physical or psychosocial demands. The physical demands were divided into energetic, biomechanical and environmental demands\(^{17}\) (Figure 1). Environmental demands were divided into physical exposures (‘climate’, ‘dust’, ‘light’, ‘noise’, ‘radiation’ and ‘vibration’), chemical exposures and biological exposures. Psychosocial demands were divided into: mental job demands, task variation characteristics, job control characteristics and social-organizational demands.\(^{18}\)

The following data were extracted from the articles on health effects: type of health effect, methods (study design, method of data collection and the time interval of data collection), participants (number, age, country) and control group (if applicable), outcome measure for prevalence, incidence or risk and confidence interval or level of significance and other outcomes. In addition, the health effects were grouped into the categories of the 10th version of the International Statistical Classification of Diseases and Related Health Problems (ICD).\(^{19}\)

Data extraction was checked randomly by HM, JS and MFD.

**Quality assessment**

The primary author appraised each article using the quality assessment lists described in table 1 and this was checked randomly by HM. For every item in the quality list, each study was rated either ‘positive’(+), ‘negative’ (-) or ‘unclear’ (?) if a study did or did not meet an item or if no clear information was stated regarding that item, respectively. The ‘not applicable’ option could be used for items on the list that did not apply to a particular study
design. For each study, a quality score was expressed as the number of items that were rated positively with respect to the total number of items. The maximum score for a study on occupational demands was three positive items out of a total of three items, while the maximum score for a study on health effects was six positive items out of a total of six items. Disagreements about study inclusion, data extraction, categorization of articles and quality assessment were resolved by consensus. Full data extraction tables on both demands and health effects can be provided by JB on request.

Data synthesis

Studies on exposure assessment for which none of the items of the quality assessment list were rated positive, were excluded from data synthesis. Studies concerning the same demand, internal load or health effect were synthesized. Presence of a control group was not required, yet only studies on health effects with a control or reference group were synthesized. In order to allow an interpretation of the magnitude of the physical exposures, a comparison to relevant regulations and professional guidelines described in Fallentin et al. was made when possible. When a more recent guideline was available, this was used (Table 2).

The levels of evidence that were used were adjusted from van Tulder:
I. Evidence: consistent, statistically significant findings in two or more studies;
II. Limited evidence: one study with statistically significant findings;
III. Conflicting evidence: inconsistent findings in multiple studies;
IV. No evidence for a relationship: not statistically significant findings in one study or consistent, not statistically significant findings in two or more studies.

The outcome of studies was considered ‘consistent’ if: i) two studies were found and both reported results in the same direction, ii) three studies were found and two reported results in the same direction, or iii) four or more studies were found and 75% of them reported results in the same direction. Other combinations of outcomes were considered ‘inconsistent’. The direction of evidence was interpreted as ‘favorable for health’ or ‘unfavorable for health’ based on the criteria below:
A. Favorable for health: prevalence, incidence or risk ratio below 1.0 and reported as significantly different from control group, or the 95% confidence interval (CI) does not include 1.0;
B. Unfavorable for health: prevalence, incidence or risk ratio above 1.0 and reported as significantly different from control group, or the 95% CI does not include 1.0.
Table 1: Quality assessment lists.

<table>
<thead>
<tr>
<th>Quality Assessment list for articles on occupational demands.</th>
<th>Item definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study sample</td>
<td>A</td>
</tr>
<tr>
<td>Exposure measurements</td>
<td>B</td>
</tr>
<tr>
<td>Analysis and data presentation</td>
<td>C</td>
</tr>
</tbody>
</table>

Quality Assessment list for articles on health effects.

<table>
<thead>
<tr>
<th>Item definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study sample</td>
</tr>
<tr>
<td>Outcome</td>
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<tr>
<td>F</td>
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<tr>
<td>G</td>
</tr>
<tr>
<td>H</td>
</tr>
<tr>
<td>Analysis and data presentation</td>
</tr>
</tbody>
</table>
Table 2: Relevant regulations and professional guidelines.

<table>
<thead>
<tr>
<th>Risk factor (exposure/demand)</th>
<th>Limit value</th>
<th>Health risk</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energetic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High energetic workload</td>
<td>25% HRR for 8-hour working day 13.0 kJ/min for 2-8 hr repetitive lifting</td>
<td>Fatigue</td>
<td>Wu and Wang [2002]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low back pain</td>
<td>Waters et al. [1993]</td>
</tr>
<tr>
<td><strong>Biomechanical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bending</td>
<td>trunk flexion &gt; 60 degrees</td>
<td>Back / neck disorders</td>
<td>ISO/CD 11226 [1995]</td>
</tr>
<tr>
<td>Manual lifting tasks</td>
<td>disc compression ≥ 3.4 kN</td>
<td>Low back pain</td>
<td>Waters et al. [1993]</td>
</tr>
<tr>
<td>Repetitive work upper extremities</td>
<td>action ≥ 2/min or cycles &lt; 30 sec</td>
<td>Upper extremity disorders</td>
<td>Sluiter et al. [2001]</td>
</tr>
<tr>
<td>Working overhead</td>
<td>upper arm elevation &gt; 60 degrees</td>
<td>Upper extremity disorders</td>
<td>ISO/CD 11226 [1995]</td>
</tr>
<tr>
<td>Walking on rough terrain</td>
<td>≥ 60 min</td>
<td>-</td>
<td>NVAB [2005]</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand-transmitted vibration</td>
<td>2.5 m/s² for 8-hour working day</td>
<td>Damage to muscular/bone structure, neurological and vascular disorders</td>
<td>European Parliament and Council of the European Union [2002]</td>
</tr>
<tr>
<td>Respirable dust (personal respirable dust concentration)</td>
<td>3.0 mg/m³</td>
<td>Respiratory disease</td>
<td>American conference of Governmental Industrial hygienists [2002]</td>
</tr>
<tr>
<td>Respirable quartz (personal respirable quartz concentration)</td>
<td>0.05 mg/m³</td>
<td>Respiratory disease</td>
<td>American conference of Governmental Industrial hygienists [2002]</td>
</tr>
</tbody>
</table>
Results

Of the 189 publications that were reviewed, 60 single publications were eligible for data synthesis. Of these, 51 publications provided information on bricklayers and 18 concerned construction supervisors (Figure 2). One study provided information on both exposures and health effects for bricklayers. Of the publications eligible for data synthesis, 32 were conducted in Europe, 20 in the U.S.A., 5 in Australia and 3 in Canada.

In this section the results on occupational demands and health effects for bricklayers will be presented, followed by the results for construction supervisors.

Occupational demands for bricklayers

A subset of 26 articles studied occupational exposures or demands for bricklayers, of which all gave information regarding physical demands and one study also described a psychosocial demand. Ten studies examined bricklayers using bricks (handled with one hand), and three studies studied bricklayers using blocks (handled with two hands, blocklayers). The remaining articles studied both or did not specify the type of bricklayer.

Figure 2: Flowchart of study in- and exclusion.
Physical demands

Physical demands were divided into the categories ‘energetic demands’, ‘biomechanical demands’ and ‘environmental demands’. In the energetic demands and biomechanical demands categories, seven studies evaluated the effects of interventions on the studied work demand. Four studies examined the effect of block weight\textsuperscript{23-26} and three studied the effect of raised bricklaying compared to conventional bricklaying.\textsuperscript{22,27,28} Other authors studied differences between different types of bricklayers (according to, for example, the type of building the bricklayer is working on)\textsuperscript{27-31} (Table 3).

Energetic demands and load

In order to quantify the intensity of the energetic load, several internal load measures were used: percentage of the heart rate reserve (HRR) and oxygen uptake\textsuperscript{26}, mean heart rate (HR)\textsuperscript{23} and energy expenditure based on HR.\textsuperscript{25} In Van der Molen et al.\textsuperscript{26}, aerobic load for blocklayers ranging between 16 and 43\% HRR during a full working day was reported. During the task ‘blocklaying’ an energetic load up to 54\% HRR was reported. Naqvi et al.\textsuperscript{25} measured – during several blocklaying tasks – energy expenditures ranging from 34 to 44 kJ/min.

In summary, two studies\textsuperscript{25,26} indicated that a substantial portion of the bricklayers will exceed the limit values for energetic workload (Table 2).

Biomechanical demands and load

Information on biomechanical demands was retrieved from 12 studies (Table 3). In all studies, external exposure measures were used to quantify the intensity, duration and frequency of the exposure related to the handling of bricks and blocks. From eight of these studies, information on working postures was also retrieved.

The handling of bricks and blocks, including actual brick- or blocklaying, takes about 35 to 60\% of the working time\textsuperscript{26,27,30}, depending on the type of bricklayer.\textsuperscript{30} Blocklayers handle approximately 240 to 294 blocks per working day, resulting in a total weight of 3200 to 3600 kg per day.\textsuperscript{26} Bricklayers are exposed to handling frequencies ranging from 87 to 262 bricks per hour.\textsuperscript{27,31} The average one-handed bricklayer spends 20\% of the working time on bricks weighing 5 to 10 kg.\textsuperscript{31} The handling of bricks weighing less than 5 kg or more than 10 kg is seen in 4\% and 7\%, respectively, of the working time.\textsuperscript{31}

For most of their working time (57–77\%), brick- and blocklayers are standing upright.\textsuperscript{27,31} The bricklayer spends 55\% of the working time in a moderately aggravating posture, while the blocklayer spends 38\% of the working time in an aggravating posture.\textsuperscript{32} Kneeling or squatting is seen during at most 4\% of the working time.\textsuperscript{29} Bending occurs during 10 to 53\% of the working time\textsuperscript{22,27,29-31}, mainly due to the picking up of bricks and mortar at ground or
knee level. Up to 84% of the bricks and 96% of the mortar are picked up below knee level. During a working day, an average bricklayer makes 912 trunk flexions with more than 20° trunk flexion and 842 flexions with more than 60° trunk flexion (approximately 105-130 times per hour). The conventional bricklayer works during 30% (129 minutes) of the working time with the arms more than 60° elevated. For nearly 70% (5 hr) of the working time the arms are 30° elevated.

The effect of raised bricklaying on the amount of time spent in a bent posture or the frequency of bending was studied by Luijsterburg et al., van der Molen et al. and Vink et al. It was found that with a scaffolding console, the time spent in a posture with more than 60° of trunk flexion was halved and the frequency reduced to 27 times per hour, and in one study it was even reduced to 12 times per day.

Exposures specific to the upper extremities were studied by Anton et al. and Vi et al. Anton et al. studied the activity of the forearm muscles, and found that during bricklaying contractions of long duration (>3 sec) are unusual. The forearm muscles are involved in moderate (3 to 15% maximal voluntary contraction, MVC) and high intensity (>31% MVC) contractions of short duration (0-3 sec during 40% of the working time). The use of the masonry trowel leads to peak moments at the wrist joint ranging from approximately 4.9 to 8.7 Nm, depending on the size of the trowel (10-12”) and whether bricks or blocks are laid.

The load on the lower back resulting from the handling of bricks and blocks was studied in seven studies, of which three used the peak compression force on L5/S1 as the outcome measure for the load on the lower back during brick- or blocklaying. Other outcome measures that were used were: cumulative spinal load, expressed as the energy stored in the lumbar spine, the duration of a certain intensity of compression forces, perceived discomfort of the lower back, mean compression forces on L5/S1, stature loss and time-integrated compression. An increase of the weight handled (up to 20 kg) and decrease of the height at which the block is handled, led to statistically significantly higher peak L5/S1-compression forces. Work with lighter bricks and blocks (less than 5 kg) resulted in maximal peak compressive forces of approximately 3.5 kN. Van der Molen et al. did not find an effect of lower block weight (11 kg compared to 14 and 16 kg) on cumulative spinal load during a full working day, nor on the energetic demand.

In summary: bricklayers are exposed to awkward working postures, including working with the arms elevated (>60°) and frequent (up to 130 times per hour) and deep (>60°) bending. Furthermore, highly repetitive movements of the upper extremities are combined with force exertion of the forearm musculature. During handling of bricks and blocks combined with a bend trunk posture the maximum disc compression force on the lower back exceeds the NIOSH threshold value of 3.4 kN (Table 2).
Environmental demands

Information on environmental demands was retrieved from 14 studies (Table 3). Of these, nine studies were concerned with dust exposure, one study with exposure to vibration, one study with exposure to ultraviolet (UV) radiation from the sun and three with exposure to noise. No studies were found regarding information on biological or chemical exposures and on the physical exposures ‘climate’ and ‘light’.

Physical demands: dust, vibration, noise and radiation

Various measurement methods were used to quantify the exposure to dust, such as self-reports, observations by an industrial hygienist and direct measurements at work.

The mean personal respirable dust exposure for bricklayers ranged from 0.160 to 29.0 mg/m³. During cutting of brick and block without dust control, concentrations ranging from 2.35 to 125 mg/m³ were measured, depending on the type of material (brick or block) and type of saw used. When using ventilation or wet cutting, concentrations ranging from 0.3 to 13.12 mg/m³ were measured. Also during other tasks, such as concrete mixing and tuck-point grinding, 13-54% of the bricklayers were exposed to concentrations exceeding the limit value of 3.0 mg/m³ as set by the American Conference of Governmental Industrial Hygienists (ACGIH).

Other authors measured the personal respirable quartz concentration during cutting of brick and block and found exposures ranging from 0.02 to 0.22 mg/m³. Flanagan found that all workers executing the task of ‘tuck-point grinding’ are exposed to quartz concentrations higher than the limit value of 0.05 mg/m³ applied by the ACGIH. Linch et al. calculated that nearly 5% of bricklayers are exposed to concentrations 2 to 5 times this value. Some bricklayers are even exposed to up to 10 times the threshold level.

Exposure to hand-transmitted vibration was measured with a self-report by Palmer et al. In total, 18% of the bricklayers surveyed reported that they were not exposed to hand-transmitted vibration. Any exposure (<2.8 m/s²) was reported by 50% of the bricklayers, and exposure greater than 5.0 m/s² was reported by 29% of the bricklayers. When the exposure to hand vibration exceeds 2.5 m/s² for 8 hr/day employers must implement HAV safety and health measures to protect exposed workers. For 8 hr/day, workers should not be exposed to above 5.0 m/s². Although bricklayers are not exposed to vibrating hand tools for 8 hr/day, Palmer et al. showed that exposure to vibration for bricklayers actually might be a serious risk (Table 2).

The noise level to which bricklayers are exposed was measured directly at work by Seixas et al., Neitzel and Seixas, Seixas et al. Average noise levels of 80.5 dBA and 87.7 dBA without hearing protection and 85.0 dBA with hearing protection were found. During the
various tasks performed by bricklayers average noise levels ranging from 84.8 dBA (during breaks, rest, lunch and cleanup) up to 98.0 dBA (during the operating of a work vehicle) were reported. Maximum noise levels ranged from 103.0 up to 116.7 dBA. The exposure action value is set at 80 dBA without hearing protection. Hearing protectors are used by 49% of the bricklayers when exposed to levels above 85 dBA, and 45% used hearing protection at exposure levels above 115 dBA.

Gies and Wright measured the exposure of Australian bricklayers to UV radiation from the sun at work. They found that 17 out of the 21 participating bricklayers exceeded the standard erythema dose (SED, 100 J m⁻²). The exposure per hour ranged from 0.95 SED to 20.38 (median 4.66 SED).

In summary, exceeding of the limit value for dust and quartz exposure was indicated by four studies. Three studies found noise levels exceeding the limit value and one study found UV-radiation to be too high.

**Psychosocial demands and load**

One study gave information on the aspect of ‘time pressure’. Nearly 60% of Dutch bricklayers surveyed rated the time pressure of their jobs as ‘not high’; 37% and 5% of the bricklayers rated the time pressure as ‘high’ and ‘extremely high’, respectively.

**Health effects for bricklayers**

The literature search retrieved 25 articles on health effects for bricklayers (Table 4). Various study designs were applied: longitudinal cohort, cross-sectional, case-control and cohort mortality designs.

**Neoplasms**

From eight studies, information concerning the prevalence, incidence or risk for various types of cancer was retrieved. Three articles provided information on the prevalence of cancer in general among bricklayers. Dong et al. found an elevated proportional mortality ratio (PMR: 127 (95% CI 117-137)), while the other authors did not find a statistically significant higher PMR or standardized mortality ratio (SMR).

Three articles gave information regarding lung cancer: a statistically significant elevated prevalence (PMR: 120 (95% CI 106-137); 134 (95%CI 112-151)) was found in two studies comparing bricklayers to the general population or other construction workers. Finkelstein and Verma did not find an increased risk for bricklayers compared to plumbers.
The risk for stomach cancer was studied in four studies, and various outcomes were reported. Elevated risks were reported by Robinson et al.\textsuperscript{52} (PMR: 208 (95% CI 142-293)) and Dong et al.\textsuperscript{51} (PMR: 142 (95% CI 105-180)). In the cohort study of Ji and Hemminki\textsuperscript{54} various types of stomach cancer were examined. They found that standardized incidence ratio’s (SIRs) for stomach cancer in general or cancer of the corpus or unspecified parts of the stomach were not statistically significant elevated compared to the general Swedish population.\textsuperscript{54} On the other hand, they found an elevated SIR for cancer of the cardia of the stomach for individuals employed as bricklayers during the period 1960-1970 (1.8 (95% CI 1.2-2.5)) or 1970-1980 (1.9 (95% CI 1.2-2.7)). Dong et al.\textsuperscript{51} and Finkelstein and Verma\textsuperscript{53} did not find an increased risk for stomach cancer for bricklayers compared to other construction workers.

Data on other types of cancer were retrieved from single studies. An increased relative risk (RR) was found for cancer of the brain (2.6 (95% CI: 1.2-5.9))\textsuperscript{55} and SIR for peritoneal mesothelioma (7.2 (95% CI 1.9-18.7)).\textsuperscript{56} No statistically significant difference between bricklayers and controls was found for: non-melanoma skin cancer\textsuperscript{57}, melanoma skin cancer\textsuperscript{52} and cancer of the bladder and bone.\textsuperscript{52}

In summary, three studies provided evidence that bricklayers are at increased risk of developing lung cancer. The evidence regarding stomach cancer, presented in five studies, is conflicting. For cancer in general or other types of cancer single studies were found, in which no or limited evidence for a relationship was found (Table 5).

**Mental disorders**

From two studies, information regarding mental disorders in general was retrieved. Compared to other construction workers, Robinson et al.\textsuperscript{52} found a higher PMR for bricklayers (187 (95% CI 133-257)), and Stattin and Järvholm\textsuperscript{58} reported a SIR of 0.8. Stattin and Järvholm\textsuperscript{58} did not provide information regarding statistical significance. In summary, the evidence presented in two studies on mental disorders is conflicting (Table 5).

**Diseases and disorders of the ear, skin and circulatory, respiratory or digestive systems**

One author found that bricklayers are at increased risk of hearing loss compared to white collar workers (prevalence ratio (PR): 1.55 (95% CI: 1.30-1.86)).\textsuperscript{59} Three authors described the risk for diseases of the circulatory system. Both Arndt et al.\textsuperscript{6} and Robinson et al.\textsuperscript{52} reported a statistically significant lower risk for bricklayers compared to the general population or other construction workers (PMR: 89 (95% CI: 83-97); SMR: 0.6 (95% CI 0.5-0.8)). Stattin and Järvholm\textsuperscript{58} found no difference (SIR 1.0, no 95% CI reported) between bricklayers and other construction workers. Arndt et al.\textsuperscript{59} examined abnormalities in diastolic blood pressure and electrocardiography but did not find an increased risk among bricklayers compared to white collar workers.
Five authors studied diseases of the respiratory system other than cancer, namely asthma\(^6\), chronic obstructive pulmonary disease (COPD)\(^6\), pneumoconiosis\(^5\), respiratory diseases in general.\(^\text{5,52,58}\) An increased risk for respiratory disease in general was found by Robinson et al.\(^\text{52}\) (PMR: 133 (95% CI 115-154)), while a decreased risk was reported by Arndt et al.\(^\text{6}\) (SMR: 0.4 (95% CI 0.1-0.8)). Li et al.\(^6\) reported an increased risk for asthma (SIR: 1.3 (95% CI 1.1-1.3)). The results regarding pneumoconiosis\(^\text{5}\) and COPD\(^\text{6}\) were not statistically significant.

Arndt et al.\(^\text{59}\) examined lung function and found an increased risk for abnormal findings at lung auscultation (PR: 2.41 (95% CI: 1.11-5.21)) among bricklayers compared to white collar workers. No increased risk for a reduced forced expiratory volume was found (PR: 1.14 (95% CI: 0.77-1.77)).\(^\text{59}\)

The risk of diseases of the digestive system was studied by Arndt et al.\(^\text{6}\) They reported not statistically significant differences between bricklayers and the general German population. Arndt et al.\(^\text{59}\) examined liver function and found bricklayers at increased risk for abnormalities compared to white collar workers (PR: 1.59 (95% CI: 1.25-2.03)).

Two studies concerned the risk for skin diseases other than skin cancer or abnormal findings of the skin. A statistically significant increased risk was reported (PMR 273 (95% CI 110-563))\(^\text{52}\) for skin diseases, but no increased risk was found for abnormal findings of the skin by Arndt et al.\(^\text{59}\)

In summary, based on three studies there is consistent evidence for a decreased risk of diseases of the circulatory system for bricklayers. Concerning the risk of diseases of the respiratory system the evidence is conflicting. Limited evidence for an increased risk was found for asthma, hearing loss and skin and liver abnormalities (Table 5).

### Diseases and disorders of the musculoskeletal system

Fourteen studies gave information regarding diseases and disorders of the musculoskeletal system. For the following complaints, no evidence for a statistically significant risk was found: rheumatoid arthritis\(^\text{62}\), complaints of the ankle and foot\(^\text{63}\) and chronic low back pain (> three months during the last year).\(^\text{64}\) Although the relative risk for osteoarthritis of the knee was significantly increased (RR: 2.1. (95% CI 1.1-4.3)), this was not the case for osteoarthritis of the hip.\(^\text{65}\)

For low back pain, an increased risk (OR: 3.0 (95% CI 2.7-3.4); 2.3 (95% CI 1.2-4.5)) was found by two authors.\(^\text{63,66}\) No difference between bricklayers and unskilled workers was reported by Latza et al.\(^\text{64}\) Stürmer et al.\(^\text{66}\) found that working for more than ten years as a bricklayer increased the risk for low back pain. Rothenbacher et al.\(^\text{67}\) and Arndt et al.\(^\text{59}\) found increased prevalences for various clinical findings of the spine (relative prevalence: 1.8 (95% CI 1.2-2.5); PR: 2.46 (95% CI: 1.67-3.63); PR: 1.76 (95% CI: 1.29-2.42)) and a medical diagnosis
related to back disorders (relative prevalence: 1.4 (1.1-1.7))\textsuperscript{67}, but not for self-reported back pain.\textsuperscript{67}

Holmström and Engholm\textsuperscript{63} reported for musculoskeletal disorders of various locations an increased OR for bricklayers compared to foremen: neck (1.8 (95% CI: 1.6-2.1)), shoulder (3.0 (95% CI: 2.6-3.4)), elbow (3.3 (95% CI: 2.9-3.9)), wrist/hand (2.7 (95% CI: 2.3-3.2)), upper back (1.6 (95% CI: 1.3-1.9)), hip (1.9 (95% CI: 1.6-2.3)) and knee (2.5 (95% CI: 2.2-2.8)). Arndt et al.\textsuperscript{59} found bricklayers to be at increased risk of musculoskeletal symptoms in the arms and legs (PR: 1.41 (95% CI: 1.11-1.78)) compared to white collar workers.

The risk for shoulder tendinitis with exposure to heavy lifting or vibration was determined by Stenlund et al.\textsuperscript{68} Exposure to vibration increased the risk for both the left (OR: 1.8 (95% CI: 1.1-3.1)) and right shoulder (OR: 1.7 (95% CI: 1.1-2.6)). Latza et al.\textsuperscript{64} examined whether bricklaying tasks (such as laying face bricks and mixing mortar) could be identified as risk factors for low back pain. None of the tasks resulted in a statistically significantly elevated OR.

Some authors reported the 10- or 12-month prevalence of musculoskeletal disorders with respect to different body regions. The prevalence of back pain among bricklayers ranged from 40-60\%\textsuperscript{22,66,67} Other prevalences reported were: hand/wrist complaints (27%), shoulder complaints (19%)\textsuperscript{22} and knee complaints (5%).\textsuperscript{69}

In summary, four studies provided consistent evidence that bricklayers are at increased risk for developing low back pain, two studies provided consistent evidence that bricklayers are at increased risk for symptoms in the arms and legs. For other diseases or disorders of the musculoskeletal system, the evidence is limited or no evidence for a relationship was found (Table 5).

Injuries and other consequences of external causes

Two studies gave information regarding the risk for accidents and injuries. Lipscomb et al.\textsuperscript{8} reported an increased incidence rate (IR: 3.1 (95% CI 1.5-5.5)) of injuries preceded by a slip or trip compared to other types of construction work. From three studies, information on mortality due to external causes was retrieved. Arndt et al.\textsuperscript{6} did not find a statistically significant SMR for several types of injury (due to non-transport accidents, falls, and being struck by falling objects). Janicak\textsuperscript{67} found a statistically significantly elevated PMR (41.6 (95% CI not reported)) for fatal head injuries. The total number of head injury deaths during a two-year interval was 31, while only seven deaths were expected amongst bricklayers. For U.S. bricklayers, death by homicide was reported to be more prevalent when compared to other U.S. construction workers (PMR: 175 (95% CI: 116-252)).\textsuperscript{52}
In summary, three studies indicate bricklayers are at increased risk of injuries. The evidence on other consequences of external causes is limited (Table 5).

**Occupational demands for construction supervisors**

Five studies gave information regarding the occupational demands for construction supervisors. Two studies gave information on physical demands: biomechanical and environmental demands were each studied once. Four studies focused on psychosocial demands (Table 6).

**Physical demands and load**

Two studies on physical demands were found, describing biomechanical demands and the environmental demand of ‘radiation’. Meijman et al. used both exposure and internal load measures to give insight into biomechanical demands for construction supervisors. During the working day, the average construction supervisor is sitting for 302 minutes a day (55% of the working day), standing for 182 minutes (33% of the working day) and walking for 62 minutes (11% of the working day). Other physical activities, such as carrying, kneeling and stooping, performing manual work, pushing and pulling and lifting, took one to seven minutes a day, spread out over one to six instances. Meijman et al. also measured hormone concentrations in order to give insight into the internal load caused by the exposures. They found that noradrenaline levels, representing physical activity during the working day, were correlated with the duration and frequency of ‘standing’ (Pearson’s correlation 0.37, 0.38 respectively) and ‘walking’ activities (Pearson’s correlation 0.33, 0.40 respectively).

According to the Dutch Guideline on Specific Occupational Demands, walking activities on rough terrain might be a risk factor when the duration exceeds 60 minutes a day (Table 2). Therefore, depending on the condition of the construction site, the biomechanical demand ‘walking’ should be taken into consideration for construction supervisors. In the ‘environmental demands’ category, one study was found. Gies and Wright measured the exposure to UV radiation in Australian construction supervisors. They found that all except one of the participating supervisors exceeded the standard erythema dose (SED, 100 J m\(^{-2}\)). The exposure per hour ranged from 1.03 to 7.58 SED (median 3.37 SED).

**Psychosocial demands and load**

Four studies provided information on mental demands. Two studies also focused on job control characteristics, and three studies described social-organizational demands.
Mental demands and load

In the occupation of construction supervisor, various cognitive domains, such as concentration, memory, decision making or attention, are used, but information on exposure in terms of intensity, duration and frequency was only provided by Meijman et al. Per working day, the construction supervisor spends time on verbal communication (300 min), inspection activities (110 min), computer and writing activities (29 min) and multitasking (10 min).

Load measures were used by Haynes and Love, Meijman et al., Strobel and von Krause and Sutherland and Davidson. Meijman et al. found that adrenaline and cortisol levels, representing mental demands during the working day, remained elevated after a working day. In a population of carpenters, representing a non-mentally demanding occupation, this effect was not found. Cortisol levels for the construction supervisors were significantly higher than during their day off. These hormone concentrations correlated with the frequency and intensity of task and activity changes (Pearson’s correlation 0.23-0.34). Pearson’s correlation coefficients ranging from 0.24 to 0.56 were found for the relation between adrenaline and cortisol levels (at the end of a working day and at 11 pm) and task interruptions (defined as starting a new task before the preceding task has come to a natural end).

Other load measures reported are the amount of pressure, stress or complaints resulting from a certain mental demand. Task interruptions and interference of both the construction process and work are perceived as stressors by 47 and 21% of the construction supervisors, respectively. Construction supervisors complain twice as often as their administrative colleagues about interruptions by persons or interference due to a lack of information. Other mental demands causing stress or pressure are the rapid change of tasks, holding conversations, financial management, making complex, difficult decisions without sufficient information and dealing with a large amount of paperwork.

Workload, working long hours

Construction supervisors endure long working hours. Meijman et al. measured on average 9 hours and 30 minutes of working time per working day (47.5 hours per week). In the structured interviews conducted by Strobel and von Krause, a substantial portion of the construction supervisors (73%) reported working over 50 hours per week.

Working long hours leads to stress in 20% of the construction supervisors, and 40% perceives pressure as a result of this demand. Construction supervisors placed this demand second in a list of ‘top-ten stressors’. Workload was perceived as the number one stressor. High or moderate pressure as a result of workload and time pressure was reported by 32-56% of the supervisors. The outcomes on these load measures are in line with the exposure on...
this demand: the intensity of the workload for construction supervisors is higher than for a reference population.68

Job control characteristics

Job control for construction supervisors has been described in terms of load measures. Cost pressure, responsibilities concerning safety and civil responsibilities were perceived as stressors by 54, 10 and 21% of the supervisors, respectively.70 Responsibility for situations not fully under one’s control was ranked 10th in the top-ten stressors.71

Social-organizational demands

Various social-organizational demands have been described using load measures such as pressure, stress or complaints resulting from these demands. Construction supervisors report the following factors leading to stress or pressure: lack of competent staff (reported by 75% of the construction supervisors), inadequate staffing (16-69%), inadequate communication (68%), multiple regulations (37%), interfering job conditions at the construction site or office (33%), tense job relations (15%) and indistinctive tasks (12%). Incompatible demands, insufficient equipment or too little appreciation for one’s achievements were reported by 10, 7 and 2% of the construction supervisors, respectively.69,70

Health effects for construction supervisors

Thirteen articles on health effects for construction supervisors were found (Table 7).

Neoplasms

Three studies on neoplasms were found. Two authors51,72 found that construction supervisors have a statistically significant increased risk of mortality due to lung cancer compared to the general population (PMR: 119 (no 95% CI reported); PMR: 124 (95% CI 103-146)). Other statistically significant increased risks were found for all types of cancer (PMR: 117 (95% CI 105-130))51 and malignant neoplasms of the connective tissue (PMR: 215).72

In summary, based on two studies, there is evidence that construction supervisors are at increased risk of lung cancer. The evidence regarding the risk for cancer in general or other types of cancer is limited (Table 5).

Mental and behavioral disorders

Information regarding mental and behavioral disorders was retrieved from six studies, with four reporting an outcome on prevalence, incidence or risk. Two studies reported that construction supervisors did not have a higher risk of mortality or disability due to mental disorders in general than the general population or other construction workers.58,72
In other studies, prevalences were reported without an indication of their significance: Campbell\textsuperscript{73} reported a prevalence of 68% concerning stress, anxiety or depression. Strobel and von Krause\textsuperscript{70} reported that construction supervisors sometimes or often report, for example: difficulties with relaxing (68%), difficulties with falling asleep (38%), feel exhausted (52%) or feel depressed (30%).

In summary, based on two studies, there is no evidence that construction supervisors are at increased risk of developing mental disorders.

**Diseases and disorders of the circulatory, respiratory, and digestive systems and skin**

Information on diseases and disorders of the circulatory and respiratory systems was retrieved from two studies. Wang et al.\textsuperscript{72} reported no statistically significant increased PMR for any of these diseases. Stattin and Järvholm\textsuperscript{58} did not report 95% CI’s for the risk of disability due to cardiovascular disorders (SIR 0.72) and respiratory disorders (SIR 0.13). In summary, no evidence was found that construction supervisors are at risk of diseases of the circulatory and respiratory systems. No studies were found on the topics of the ‘digestive system’ or ‘skin, subcutaneous tissue’.

**Diseases and disorders of the musculoskeletal system**

The risk of osteoarthritis for construction supervisors was studied by Järvholm et al.\textsuperscript{65} They found that construction supervisors are not at increased risk for osteoarthritis of the knee or hip compared to white collar workers. Holmström and Engholm\textsuperscript{63} reported prevalences of musculoskeletal disorders and found higher 12-month prevalences for all body locations for construction supervisors compared to office workers. Strobel and von Krause\textsuperscript{70} reported that 40% of construction supervisors have tense shoulders and back problems, which the supervisors themselves related to stress. Stenlund et al.\textsuperscript{74} studied the prevalence and risk factors for signs of a clinical entity of shoulder tendonitis. They found that for construction supervisors, the exposure to hand-arm vibration was a statistically significant risk factor for signs of tendonitis for both the right shoulder (OR: 1.66 (95 % CI 1.06-2.61)) and left shoulder (OR: 1.84 (95% CI 1.10-3.07)). No relation was found between lifting and shoulder tendonitis.

In summary, limited evidence was found that construction supervisors are at risk for various diseases of the musculoskeletal system (Table 5).

**Injuries and other consequences of external causes**

Six studies gave information for construction supervisors regarding injuries and other consequences of external causes, including mortality. Kisner and Fosbroke\textsuperscript{75} reported an IR of fatalities of 9 per 100,000 workers, which is three times higher than the IR for executives
in other industries. Significant increased risks reported were: for fatal occupational injuries (IR: 9.6 per 100,000 workers (95% CI: 6.7-13.7)), due to falls (IR: 2.2 (95% CI: 1.1-4.6))\textsuperscript{79}, mortality due to accidents (RR: 2.48 (95% CI: 1.76-3.51))\textsuperscript{55} and mortality due to transportation accidents (PMR: 128).\textsuperscript{72} However, in other studies no statistically significant increased risk was found for fatal falls\textsuperscript{72} and fatal transportation accidents.\textsuperscript{76} For injuries due to slipping and tripping\textsuperscript{8} and fatal accidents due to machinery, electric current\textsuperscript{76} or poisoning\textsuperscript{72} no statistically significant increased risk was found.

In summary, based on two studies, consistent evidence was found for a statistically significant increased risk of fatal injuries and accidents in general. However, the evidence on specified injuries, accidents or other consequences of external causes of mortality is conflicting, limited or no evidence for a relationship was found (Table 5).
### Table 3: Occupational demands for bricklayers.

<table>
<thead>
<tr>
<th>No</th>
<th>Reference</th>
<th>Country</th>
<th>Population</th>
<th>Physical demands</th>
<th>Psychosocial demands</th>
<th>Quality score</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>Carlsten et al. [2007]</td>
<td>U.S.A.</td>
<td>-</td>
<td>x</td>
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<td>+ + + 3 of 3</td>
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<tr>
<td>2</td>
<td>Van der Molen et al. [2007]</td>
<td>Netherlands</td>
<td>BL</td>
<td>x</td>
<td>x</td>
<td>+ + + 3 of 3</td>
</tr>
<tr>
<td>3</td>
<td>Anton et al. [2005]</td>
<td>U.S.A.</td>
<td>BL</td>
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<td>+</td>
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<td>x</td>
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<td>5</td>
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<td>BR</td>
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<tr>
<td>7</td>
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<td>U.S.A.</td>
<td>-</td>
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<td>- + + 2 of 3</td>
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<tr>
<td>16</td>
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<td>22</td>
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<td>BR &amp; BL</td>
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<td>23</td>
<td>De Looze et al. [1996]</td>
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<td>BR</td>
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<td>+ + + 3 of 3</td>
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</table>
Table 4: Health effects for bricklayers.

<table>
<thead>
<tr>
<th>No</th>
<th>Reference</th>
<th>Country</th>
<th>Design</th>
<th>Control / reference group</th>
<th>M/D</th>
<th>Quality score</th>
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<td>Denmark</td>
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<td>white collar workers</td>
<td>D</td>
<td>+ + + + + + 6 of 6</td>
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<td>Sweden</td>
<td>longitudinal cohort</td>
<td>all economically active individuals in entire cohort</td>
<td>D</td>
<td>- + + + + + 5 of 6</td>
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<tr>
<td>3.</td>
<td>Li et al. [2008b]</td>
<td>Sweden</td>
<td>longitudinal cohort</td>
<td>all economically active individuals in entire cohort</td>
<td>D</td>
<td>+ + + + + + 6 of 6</td>
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<tr>
<td>4.</td>
<td>Suárez et al. [2007]</td>
<td>Italy, France, Spain</td>
<td>case-control</td>
<td>random sample from same region, stratified by age and sex</td>
<td>D</td>
<td>- + n.a. n.a. + + 3 of 6</td>
</tr>
<tr>
<td>5.</td>
<td>Ji and Hemminki [2006]</td>
<td>Sweden</td>
<td>cohort study</td>
<td>the economically active Swedish population</td>
<td>D</td>
<td>- + n.a. n.a. n.a. + 2 of 6</td>
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<tr>
<td>7.</td>
<td>Finkelstein and Verma [2005]</td>
<td>Canada</td>
<td>cohort mortality study</td>
<td>plumbers</td>
<td>M</td>
<td>+ + n.a. n.a. n.a. + 3 of 6</td>
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<td>8.</td>
<td>Luijsterburg et al. [2005]</td>
<td>Netherlands</td>
<td>intervention</td>
<td>-</td>
<td>D</td>
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<td>longitudinal cohort</td>
<td>general German population</td>
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<td>D</td>
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M= mortality as outcome; D = disease as outcome; n.a. = not applicable
Table 4 (continued): Health effects for bricklayers.

<table>
<thead>
<tr>
<th>No</th>
<th>Reference</th>
<th>Country</th>
<th>Design</th>
<th>Control / reference group</th>
<th>M/D</th>
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<td>white collar workers</td>
<td>D</td>
<td>+</td>
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<tr>
<td>21</td>
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<td>U.K.</td>
<td>cohort mortality study</td>
<td>PMR: general male population MOR: rest of the study population</td>
<td>M</td>
<td>+</td>
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<tr>
<td>22</td>
<td>Hartmann [1995]</td>
<td>Germany</td>
<td>cross-sectional</td>
<td>-</td>
<td>D</td>
<td>+</td>
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<td>U.S.A.</td>
<td>cohort mortality study</td>
<td>deaths due to that cause among all construction workers</td>
<td>M</td>
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<tr>
<td>24</td>
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<td>Sweden</td>
<td>cross-sectional</td>
<td>foremen</td>
<td>D</td>
<td>+</td>
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</tbody>
</table>

M= mortality as outcome; D = disease as outcome; n.a. = not applicable
Table 5: Evidence on health effects.

<table>
<thead>
<tr>
<th>Health effect</th>
<th>Evidence</th>
<th>Direction of risk reported and reference(s)</th>
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<tbody>
<tr>
<td><strong>Neoplasms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung cancer</td>
<td>Consistent: increased risk</td>
<td>2: unfavorable for health [Dong et al., 1995; Robinson et al., 1995] 1: no statistically significant risk [Finkelstein and Verma, 2005]</td>
</tr>
<tr>
<td>Stomach cancer</td>
<td>Conflicting</td>
<td>2: unfavorable for health [Dong et al., 1995; Robinson et al., 1995] 3: no statistically significant risk [Dong et al., 1995; Finkelstein and Verma, 2005; Ji and Hemminki, 2006]</td>
</tr>
<tr>
<td>Cancer of the brain</td>
<td>Limited</td>
<td>1: unfavorable for health [Aronson et al., 1999]</td>
</tr>
<tr>
<td>Peritoneal mesothelioma</td>
<td>Limited</td>
<td>1: unfavorable for health [Hemminki and Li, 2003]</td>
</tr>
<tr>
<td><strong>Mental disorders</strong></td>
<td>Conflicting</td>
<td>1: unfavorable for health [Robinson et al., 1995] 1: favorable for health [Stattin and Järvholm, 2005]</td>
</tr>
<tr>
<td><strong>Disease of the ear</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hearing loss</td>
<td>Limited</td>
<td>1: unfavorable for health [Arndt et al., 1996]</td>
</tr>
<tr>
<td>Disease of the skin</td>
<td>Limited</td>
<td>1: unfavorable for health [Robinson et al., 1995]</td>
</tr>
<tr>
<td><strong>Disease of the circulatory system</strong></td>
<td>Consistent: decreased risk</td>
<td>2: favorable for health [Robinson et al., 1995; Arndt et al., 2004] 1: no statistically significant risk [Stattin and Järvholm, 2005]</td>
</tr>
<tr>
<td><strong>Disease of the respiratory system</strong></td>
<td>Conflicting</td>
<td>1: unfavorable for health [Robinson et al., 1995] 1: favorable for health [Arndt et al., 2004]</td>
</tr>
<tr>
<td>Asthma</td>
<td>Limited</td>
<td>1: unfavorable for health [Li et al., 2008a]</td>
</tr>
<tr>
<td><strong>Disease of the digestive system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver abnormalities</td>
<td>Limited</td>
<td>1: unfavorable for health [Arndt et al., 1996]</td>
</tr>
<tr>
<td><strong>Disease of the musculoskeletal system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low back pain</td>
<td>Consistent: increased risk</td>
<td>4: unfavorable for health [Arndt et al., 1996; Rothenbacher et al., 1997b; Stürmer et al., 1997; Holmstrom and Engholm, 2003] 1: no statistically significant risk [Latza et al., 2000]</td>
</tr>
<tr>
<td>Complaints of arms/legs in general</td>
<td>Consistent: increased risk</td>
<td>2: unfavorable for health [Arndt et al., 1996; Holmstrom and Engholm, 2003]</td>
</tr>
<tr>
<td>Osteoarthritis of the knee</td>
<td>Limited</td>
<td>1: unfavorable for health [Järvholm et al., 2008]</td>
</tr>
<tr>
<td><strong>Injuries and other consequences of external causes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Fatal) Injuries and accidents</td>
<td>Consistent: increased risk</td>
<td>1: unfavorable for health [Janicak, 1998] (fatal head injuries) 1: unfavorable for health [Lipscomb et al., 2006] (injuries due to tripping and slipping) 1: no statistically significant risk [Arndt et al., 2004]</td>
</tr>
<tr>
<td>Homicide</td>
<td>Limited</td>
<td>1: unfavorable for health [Robinson et al., 1995]</td>
</tr>
<tr>
<td>Alcohol-associated disease</td>
<td>Limited</td>
<td>1: unfavorable for health [Robinson et al., 1995]</td>
</tr>
</tbody>
</table>
Table 5 (continued): Evidence on health effects.

<table>
<thead>
<tr>
<th>CONSTRUCTION SUPERVISORS</th>
<th>Neoplasms (general)</th>
<th>Limited</th>
<th>1: unfavorable for health [Dong et al., 1995]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lung cancer</td>
<td>Consistent: increased risk</td>
<td>2: unfavorable for health [Dong et al., 1995; Wang et al., 1999]</td>
</tr>
<tr>
<td></td>
<td>Malignant neoplasms of connective tissue</td>
<td>Limited</td>
<td>1: unfavorable for health [Wang et al., 1999]</td>
</tr>
</tbody>
</table>

Disease of the musculoskeletal system

| Complaints of: neck, shoulder, elbow, wrist/hand, upper back, lower back, hip, knee, ankle/foot | Limited | 1: unfavorable for health [Holmstrom and Engholm, 2003] |

Injuries and other consequences of external causes

| Fatal injuries or accidents (general) | Consistent: increased risk | 2: unfavorable for health [Aronson et al., 1999; Jackson and Loomis, 2002] |
| Injury due to falls | Conflicting | 1: unfavorable for health [Jackson and Loomis, 2002] |
| Transportation accidents | Limited | 1: unfavorable for health [Wang et al., 1999] |

Table 6: Occupational demands for construction supervisors.

<table>
<thead>
<tr>
<th>No</th>
<th>Reference</th>
<th>Country</th>
<th>CS</th>
<th>Construction supervisors (CS)</th>
<th>Physical demands</th>
<th>Psychosocial demands</th>
<th>Quality score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Energetic</td>
<td>Biomechanical</td>
<td>Environmental Physical</td>
<td>Job control Social-organizational</td>
</tr>
<tr>
<td>1.</td>
<td>Haynes and Love [2004]</td>
<td>Australia</td>
<td>CS</td>
<td>x</td>
<td>x</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2.</td>
<td>Gies and Wright [2003]</td>
<td>Australia</td>
<td>CS</td>
<td>x</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.</td>
<td>Meijman et al. [1999]</td>
<td>Netherlands</td>
<td>CS</td>
<td>x</td>
<td>x</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5.</td>
<td>Sutherland and Davidson [1993]</td>
<td>U.K.</td>
<td>CS</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>+</td>
</tr>
</tbody>
</table>
Table 7: Health effects for construction supervisors.

<table>
<thead>
<tr>
<th>No.</th>
<th>Reference</th>
<th>Country</th>
<th>Design</th>
<th>Control / reference group</th>
<th>M/D</th>
<th>Quality score</th>
<th>Item D</th>
<th>Item E</th>
<th>Item F</th>
<th>Item G</th>
<th>Item H</th>
<th>Item I</th>
<th>Quality (points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Järvholm et al. [2008]</td>
<td>Sweden</td>
<td>longitudinal cohort</td>
<td>white collar workers</td>
<td>D</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>6 of 6</td>
</tr>
<tr>
<td>3</td>
<td>Lipscomb et al. [2006]</td>
<td>U.S.A.</td>
<td>cross-sectional</td>
<td>-</td>
<td>D</td>
<td>-</td>
<td>-</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>+</td>
<td></td>
<td>1 of 6</td>
</tr>
<tr>
<td>4</td>
<td>Stattin and Järvholm [2005]</td>
<td>Sweden</td>
<td>longitudinal cohort</td>
<td>other construction workers</td>
<td>D</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
<td>4 of 6</td>
</tr>
<tr>
<td>5</td>
<td>Holmström and Engholm [2003]</td>
<td>Sweden</td>
<td>cross-sectional</td>
<td>-</td>
<td>D</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
<td>+</td>
<td>-</td>
<td></td>
<td>3 of 6</td>
</tr>
<tr>
<td>6</td>
<td>Jackson and Loomis [2002]</td>
<td>U.S.A.</td>
<td>cohort mortality study</td>
<td>general population</td>
<td>M</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>-</td>
<td></td>
<td>2 of 6</td>
</tr>
<tr>
<td>7</td>
<td>Aronson et al. [1999]</td>
<td>Canada</td>
<td>cohort mortality study</td>
<td>workers in the same</td>
<td>M</td>
<td>-</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>+</td>
<td></td>
<td>2 of 6</td>
</tr>
<tr>
<td>8</td>
<td>Wang et al. [1999]</td>
<td>U.S.A.</td>
<td>cohort mortality study</td>
<td>general population</td>
<td>M</td>
<td>-</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>-</td>
<td></td>
<td>1 of 6</td>
</tr>
<tr>
<td>9</td>
<td>Teschke et al. [1997]</td>
<td>Canada</td>
<td>case-control</td>
<td>matched controls never</td>
<td>D</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
<td>+</td>
<td>+</td>
<td></td>
<td>4 of 6</td>
</tr>
<tr>
<td>10</td>
<td>Pratt et al. [1997]</td>
<td>U.S.A.</td>
<td>cross-sectional</td>
<td>-</td>
<td>M</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>-</td>
<td></td>
<td>2 of 6</td>
</tr>
<tr>
<td>11</td>
<td>Dong et al. [1995]</td>
<td>U.K.</td>
<td>cohort mortality study</td>
<td>general population</td>
<td>M</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>+</td>
<td></td>
<td>2 of 6</td>
</tr>
<tr>
<td>13</td>
<td>Stenlund et al. [1993]</td>
<td>Sweden</td>
<td>cross-sectional</td>
<td>-</td>
<td>D</td>
<td>+</td>
<td>+</td>
<td>n.a.</td>
<td>n.a.</td>
<td>+</td>
<td>+</td>
<td></td>
<td>4 of 6</td>
</tr>
</tbody>
</table>

M = mortality as outcome; D = disease as outcome; n.a. = not applicable
Discussion

Occupational demands

The studies presented in this review point to a number of occupational demands and health effects for bricklayers and construction supervisors. We found that energetic, biomechanical and environmental demands for bricklayers in terms of duration, intensity and frequency have been studied frequently over the past 15 years. By contrast, however, scant attention has been paid to the psychosocial demands on bricklayers. Next to the high energetic load for bricklayers the following main biomechanical demands emerged from the literature: repetitive handling of bricks, blocks and a masonry trowel and working postures involving frequent deep bending and working with elevated arms. These biomechanical demands result in intense use of forearm musculature and a high load on the lower back. With respect to environmental demands only the exposure to dust, respirable quartz and noise has been comprehensively studied by multiple authors.

The literature on the physical demands for construction supervisors is limited: no studies were found concerning energetic demands, and biomechanical and environmental demands were each considered in a single publication only. From both exposure and load measurements it appears that walking and standing are the most important physically demanding activities for construction supervisors. Multiple studies concerning the psychosocial demands for construction supervisors were found. The effects of the mentally demanding nature of the tasks and activities of the construction supervisor were reflected in internal load measures. Workload, time pressure and working long hours were perceived as stressors by construction supervisors. This applies, to a lesser extent, to factors related to job control, except for cost pressure. Other major stressors were found in social-organizational demands: more than 50% of the construction supervisors reported stress resulting from, for example, communication and staffing problems.

As shown in Table 3, 23 out of 26 studies on the demands for bricklayers attained ≥2 out of 3 points in the quality assessment. Of the studies scoring 2 out of 3 points none of them met item A of the quality assessment list of occupational demands. In other words, most authors applied useful measurement methods and quantified exposures (duration, intensity or frequency) but did not report their study sample. For the studies concerning demands for construction supervisors, 4 out of 5 studies on the demands for construction supervisors did not attain the full quality score because they did not assess exposure in terms of duration, frequency and intensity. We believe that this is a major gap in the available knowledge of the demands for construction supervisors.
Health effects

On the one hand, concerning health effects, it can be concluded that there is evidence that bricklayers are at a higher risk for developing lung cancer, low back pain, arm and leg complaints and for getting injuries. On the other hand, the risk of mortality due to diseases of the circulatory system seems lower for bricklayers, which implies a favorable effect on health. Concerning the risk of stomach cancer, mental disorders and diseases of the respiratory system, the evidence is conflicting. Limited evidence for an increased risk was found for some types of cancer, hearing loss, asthma, skin diseases and osteoarthritis of the knee.

For construction supervisors, there is evidence that they are at increased risk for mortality due to lung cancer and injuries. Limited evidence of an increased risk was found for complaints of the musculoskeletal system, cancer in general and cancer of the connective tissues in particular.

Job-specific versus branch-specific

Based on the available literature notable differences between the demanding natures of the two occupations have been found. The findings on the demands support the relevance of a job-specific approach of a WHS for construction workers. However, a valid comparison of demands could not be made. For example, a lack of information on psychosocial demands for bricklayers does not indicate that these demands are not of any relevance for these workers.

When comparing the two occupations on health effects, two similarities were found: the increased risk of lung cancer and the increased risk of (fatal) injuries. Therefore, there is a scientific basis to include respiratory functioning and safety-related issues in the WHS for both occupations. These health effects might possibly be regarded as branch-specific, but they are not solely job-specific. However, job-specific health effects have also been found. Bricklayers, for example, are at increased risk for low back disorders, while this is not the case for construction supervisors. Attention to biomechanical risk factors and the resulting health effects seems, therefore, warranted in a WHS for bricklayers and less so for construction supervisors.

Strengths and limitations

This study, which is the first systematic review of the occupational demands and health effects for bricklayers and construction supervisors, has several strengths. First, the literature search undertaken was sensitive and comprehensive. The search strategy included multiple databases, peer-reviewed articles and grey literature to maximize the possibility of retrieving relevant studies. It could be argued that within the scope of developing a
A systematic review

WHS for a particular occupation a job-specific approach is not necessary. Information from other occupations or even industries could be extrapolated to specific tasks and jobs for identifying particular risks. However, developing a WHS is more than identifying risks, it is an ongoing signalling and evaluation of workers’ health and work capacity. That is when the surplus value of the job-specific approach comes into play, it allows for adjustment of the goals of the WHS or effective intervention measures for the specific occupation at hand. For example, while one knows that construction workers are at risk for low back pain, this pain might be caused by vibration, lifting, bending or a combination of these. In a job-specific approach quantitative knowledge of these specific exposures for the bricklayer is available, which provides an opportunity to choose the potentially most effective intervention aimed at reducing the specific risk for the bricklayer. Therefore, taking into account the context in which this systematic review was embedded, a job-specific approach was chosen a priori. In accordance with this choice we strictly applied our inclusion rule regarding the population. When it was not absolutely clear that the study population concerned bricklayers or supervisors for 50% or more of the subjects (e.g. Firth et al.78, Firth et al.79, Baarts et al.80) the study was not included. As a result of this we might have missed information for those occupations.

Furthermore, it could be argued that a job-specific search of health effects might not be the most appropriate way to obtain a clear understanding of the relationship between health effects and a specific occupation. Health effects for bricklayers may be explained by exposures resulting from their occupation, but our approach does not allow for statements of causal relationships between demands and health effects for bricklayers. Only a few authors have examined the relationship between occupational demands and certain health effects within a population of bricklayers. They found that the association between specific bricklaying tasks and the one-year prevalence of LBP is not statistically significant81, nor is the exposure to lifting and shoulder tendinitis.74 Only the exposure to hand-transmitted vibration for bricklayers compared to foremen is associated with an increased risk of signs of shoulder tendinitis.74 This limited information on the relationship between demands and possible health effects — resulting from a job-specific approach — might be resolved by using knowledge from systematic reviews of occupational demands in general and related health effects.82-85

In this review, quality lists were used to assess the methodological quality of the included studies. The key components of the design, instead of an aggregate score, were reflected.86 However, the quality scoring was not used as a weight in the analysis but was presented with the objective of increasing transparency for the reader. The evidence for health effects presented in this review, however, was limited by study quality and should be interpreted with caution. For example, the evidence for diseases or disorders of the musculoskeletal system for bricklayers was based on eight studies. Of these, all scored three or more points out of six possible points, indicating a reasonable foundation of the evidence. The
cross-sectional design of most of these studies obstructs the ability to obtain a full quality score. However, of the studies reporting a significantly increased risk for injuries and other consequences of external causes, only one out of the three studies scored more than half of the possible points. A general limitation regarding the quality of studies on health effects using mortality as an outcome, is the bias introduced by using this outcome measure. For example, the evidence that construction supervisors are at increased risk of lung cancer is based on two cohort mortality studies. Although this evidence cannot be regarded as strong — several confounders might have played a role — it might give rise to a new approach in assessing these health effects for construction supervisors or provide a closer look at the actual exposures in this occupation.

Evidence base of exposure limits

Whenever possible, we decided to compare physical demands to relevant regulatory or professional guidelines for physical workload. As pointed out, several demands for bricklayers exceed regulatory or professional guidelines, indicating a risk for bricklayers due to these exposures and emphasizes the need for health monitoring. However, a major problem of the guidelines for acceptable physical exposure regarding health effects is the lack of knowledge of pathophysiological mechanisms. Furthermore, not all guidelines and standards are based on scientific knowledge: they are liable to political, cultural and economic considerations. Inconsistency and limited scientific credibility result from this. Therefore, the guidelines should not be interpreted as absolute limits and it should be recognized that the risk of adverse health effects is not eliminated when exposures are below the threshold value.

In contrast with physical demands, no norms exist for psychosocial demands. The reported demands for construction supervisors are, therefore, more difficult to interpret. The authors suggest two strategies that might be useful when considering psychosocial demands: i) use instruments to measure psychosocial work characteristics that are well validated in a specific population and for which cut-off points have been specified, such that exceeding of these cut-off scores might indicate an increased risk of related health effects and ii) assess related health effects and complaints, such as stress, depression or anxiety, that are possibly related to psychosocial work demands. An increased risk or prevalence of these health effects indicates a psychosocial load that is too high for the workers.

Towards a job-specific WHS: supplementing the evidence

Not all literature retrieved was suitable for inclusion or data synthesis, mainly due to the population studied or a lack of a priori defined outcome measures. These studies could not contribute to determining demands in terms of duration, intensity or frequency or health effects in terms of risk. However, these sources may provide relevant, complementary
information that is useful when establishing specific goals for the job-specific WHS for bricklayers or supervisors. In particular, these sources include Center for Construction Research and Training (CPWR) and Arbouw (Dutch Health & Safety Institute in the Construction Industry). According to their data\textsuperscript{89}, chart book\textsuperscript{90} or expert knowledge\textsuperscript{91}, there are more relevant topics that must be taken into account when developing a WHS for the occupations under study (Figure 3 and Figure 4). For example environmental demands for bricklayers also include skin contact with cement\textsuperscript{91,92} and contact with chemical substances, which is related to the risk of contact dermatitis and irritation of the skin.\textsuperscript{93} Other potential environmental risks for bricklayers are: prolonged standing\textsuperscript{91} and working in the cold, heat, wind or rain.\textsuperscript{91,92} Other relevant safety issues reported for bricklayers include: insufficient lighting, working with electrical devices and hazardous substances and working at heights.\textsuperscript{91} All of these issues can lead to various types of injuries and accidents.\textsuperscript{90}

In summary, this review provides a scientific basis for developing a job-specific WHS. Information from other sources, however, is needed to fill the existing gaps and to enable the goal-oriented approach typical of the job-specific WHS. In addition to information from literature published after the time frame of this review (e.g. Faber et al.\textsuperscript{94}, Hess et al.\textsuperscript{95}, Meeker et al.\textsuperscript{96}), other methods such as a questionnaire survey, must be used in order to supplement and validate the evidence from the literature.
Figure 3: Content of a job-specific WHS program for bricklayers in which evidence presented in this review as complementary information is embedded (sources between brackets).

<table>
<thead>
<tr>
<th>Job characteristics/conditions regarded as risks for bricklayers:</th>
<th>Plausible health effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Psychosocial</strong>&lt;br&gt;- Mental&lt;br&gt;- Craftsmanship [Arbouw]&lt;br&gt;- Concentration [Arbouw]&lt;br&gt;- Accuracy [Arbouw]</td>
<td></td>
</tr>
<tr>
<td>Job characteristics/conditions regarded as risks for construction supervisors:</td>
<td>Plausible health effects</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| **Physical**  
- Biomechanical  
  - Walking [this Review]  
  - Standing [this Review]  
  - Climbing ladders or scaffolding [Arbouw] | **Musculoskeletal system**  
- Complaints of the musculoskeletal system [this Review]  
- Overexertion [CPWR] |
| **Environmental**  
- Physical  
  - UV-radiation [this Review]  
  - Dust [Arbouw]  
  - Hand-transmitted vibration [Arbouw]  
  - Noise [Arbouw]  
  - Climate [Arbouw]  
- Chemical  
  - Toxic substances, vapours or gases [Arbouw] | **Neoplasms**  
- Cancer in general [this Review]  
- Lung cancer [this Review]  
- Cancer of connective tissue [this Review]  
- Ear  
  - Noise-induced hearing loss [CPWR, Arbouw] |
| **Safety**  
- Working with electric devices [Arbouw]  
- Working at heights [Arbouw]  
- Working nearby heavy equipment [Arbouw] | **Injuries and other consequences of external causes**  
- (Fatal) accidents and injuries [this Review]  
- Transportation accidents [this Review]  
- Falls [CPWR, Arbouw]  
- Electrocution [CPWR]  
- Vehicle / heavy equipment [CPWR] |
| **Psychosocial**  
- Mental  
  - Verbal communication [this Review]  
  - Inspection activities [this Review]  
  - Computer, writing activities [this Review]  
  - Decision making [this Review]  
  - Task interruptions and interference [this Review]  
- Workload  
  - High workload and time pressure [this Review]  
  - Working long hours [this Review]  
  - Job control  
  - Cost pressure [this Review]  
  - Responsibilities concerning safety [this Review]  
  - Social-organizational  
  - Lack of competent staff [this Review]  
  - Inadequate staffing [this Review]  
  - Inadequate communication [this Review]  
  - Multiple regulations [this Review]  
  - Tense job relations [this Review] | **Mental and behavioral disorders**  
- Stress-related disorders [Arbouw] |

Figure 4: Content of a job-specific WHS program for construction supervisors in which evidence presented in this review as complementary information is embedded (sources between brackets).
References


42. ACGIH. Threshold limit values and biological exposures indices for chemical substances and physical agents. Cincinnati, OH: ACGIH; 2002.


90. CPWR - The Center for Construction Research and Training. The Construction Chart Book (produced with support from the National Institute for Occupational Safety and Health grant number OH008307). 2010.


