Musculoskeletal problems in bricklayers, carpenters and plasterers: Literature review and results of site visits

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Summary

This project was a preliminary ergonomic investigation of the factors that can lead to musculoskeletal disorders in construction workers.

Objectives

1. To carry out a comprehensive literature review of epidemiological and ergonomic studies of musculoskeletal complaints among bricklayers, carpenters and plasterers.

2. To carry out site visits to observe and discuss the work undertaken by plasterers, carpenters and bricklayers to identify how the work affects the risks of musculoskeletal disorders in these trades.

Main Findings

1. Construction is a high risk industry for musculoskeletal disorders.

2. Existing HSE data on the prevalence of musculoskeletal ‘trouble’ shows that while there is considerable variation between trades in the levels of problems reported in different parts of the body, there is no distinct separation of any one trade from the rest of the industry. Instead, the parts of the body worst affected appear to be trade-specific.

3. Overall, the published scientific literature concentrates on disorders of the low back, the upper limb, and the knees.

4. There is extensive European literature on brick and block laying. The precise practices carried out depend upon the styles of building fashionable in the particular culture. Bricklaying is seen as strenuous and a high risk task for musculoskeletal disorders, particularly of the low back and wrists.

5. Carpentry comprises a wide variety of sub-trades and tasks. The allocation of jobs to the trade appears to be partly culturally determined with dry lining work being described as a plastering task in the UK and a carpenter’s task in the USA. The ergonomics literature on carpentry and epidemiology of carpenters is fairly wide ranging.

6. The ergonomics literature on plastering tasks is restricted to recent work on drylining. There is no literature on wet plastering nor on floor screeding. Dry lining is seen as a heavy and high risk task due to the need for the manual handling of large and heavy sheets of plasterboard.
7. Site observations of plasterers showed that it is physically demanding involving manual handling of heavy materials and also requiring reach, flexibility to work in a variety of awkward postures, including on raised platforms, and also requiring endurance.

8. Site observations of carpenters showed that tasks can vary widely. The self-perception of carpenters working indoors appeared to be that they were concerned with general safety issues rather than musculoskeletal issues specifically, suggesting they did not see their tasks as particularly straining on the musculoskeletal system.

9. Site observations of bricklayers showed a variety of problems, especially concerned with handling of heavy materials. Issues of lack of space, poor work planning, variation in height and working in awkward postures were identified. The weight of concrete blocks is clearly an important issue. As with plastering, strength and flexibility are needed.

10. A recurring theme was that the commercial pressures on workers force them to work as quickly as possible and therefore they risk compromising safety.

Main Recommendations

1. Those involved in designing buildings, and planning and managing their construction need to take into account the risks to musculoskeletal health of the different available construction methods, and to plan the structure and the construction processes in ways which allow these risks to be reduced so far as is reasonably practicable.

2. There is a need for the construction industry to make more extensive use of the aids that are already available to reduce the risks of manual handling and postural stress in construction.

3. There is a need for further scientific work to be carried out to examine the ergonomic risk factors of wet plastering and floor screeding.
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1. INTRODUCTION

1.1. Musculoskeletal disorders as a problem in the construction industry

According to a number of epidemiological and ergonomic studies, the construction industry is
in the top three occupations for work-related musculoskeletal disorders (WMSDs), along with
the manufacturing and meat processing industries. WMSDs are clinical and sub-clinical
conditions affecting the musculoskeletal system of the body, i.e., the muscles, tendons, nerves
and bones. Symptoms usually include discomfort, pain, numbness or tingling in a body
region. Disorders of the bone are typically bruises, micro-fractures, cracks or splintering.
They are associated with four main risk factors, undesirable force, duration, repetition and the
adoption of static and awkward postures. Research suggests that both extreme work postures
and static work postures contribute to the occurrence of low back and musculoskeletal
symptoms. These conditions are also referred to as “repetitive strain injuries” (RSI), “cumula-
tive trauma disorders” (CTD) or “occupational overuse syndromes” (OOS).

Disorders caused by manual handling and lifting include low-back muscle strains and inter-
vertebral disc lesions. Those caused by forceful repetitive movements of the upper limb
include carpal tunnel syndrome, tenosynovitis, peritendinitis and epicondylitis.

Low back pain and neck and shoulder pain are associated with unsuitable postures. Some
studies also have shown that there is a relationship between psychosocial factors and work-
related upper limb disorders. Psychosocial factors include the amount of control over one’s
job, which is particularly important where the demands are high (e.g., in piecework). In these
situations where the worker has little control, the job is usually very stressful.

Tasks carried out within construction trades require the use of hand tools and power tools,
entailing the use of multiple body regions, constant movement in awkward positions, and
repetitive, forceful, use of the back and upper and lower extremities.

The particular tasks undertaken by construction workers largely depend on the trades they are
employed in and the particular construction site they are on. Tasks can vary throughout the
day, but can also be repetitive. Construction workers may have little or no control over which
task can be carried out at a particular time, as this can depend on environmental conditions
such as inclement weather when working outdoors or at height, and also upon other condi-
tions such as the delivery of materials.

Tasks are often performed at maximum pace to meet deadlines, placing the worker at
increased risk of not only chronic musculoskeletal disorders but also of acute injuries. The
phenomenon of intermittent employment with various employers, from periods of days to
several years, adds unfamiliar work practices and environments to this hazardous equation.

1.2. The scale of the problem

The majority of research into musculoskeletal problems has taken place in the manufacturing
and meat packing industry, which are relatively controlled and organised environments within
which studies can take place. The majority of the research specific to the construction indus-
try on the prevalence of musculoskeletal disorders has been published in the USA, Canada,
Sweden, Denmark and Finland. The data has been collated from sources such as workers’ compensation databases, (e.g., Schneider and Susi, 1994), bills from physicians, hospital data base records, postal questionnaires, and phone questionnaires.

The US Department of Labor Employment and Training Administration Database on Job Demands (DOL/ETA) shows that, compared to non-construction occupations, construction occupations require greater amounts of strength and involve more stooping, crawling, crouching kneeling, climbing and balancing (Schneider et al., 1998). In particular, climbing is very fatiguing and could result in muscle strain, potentially resulting in a loss of balance that could lead to a fall and serious injury.

According to Christensen et al. (1991), the number of musculoskeletal disorders reported to the Danish Labour Inspection Service is increasing. Another Danish study (Holmström et al., 1995), showed that the one year prevalence of symptoms from the lower back was 42% and from the neck/shoulder was 40%.

Broersen et al. (1995) compared questionnaire data from two Dutch periodic occupational health surveys carried out in the general working population and the construction industry. Greater percentages of workers in the construction industry complained about the physical demands of the job or of backache than in the general working population. They attributed this to the “average” job in the construction industry being physically very strenuous compared to most other occupations in the general survey. They also found that groups of employees with the same occupation from the two data sets differed systematically but the rank order of eight occupations was similar in both data sets. They therefore attributed some of the actual differences to geographical differences between the two surveys.

The construction industry was the industry with the fourth highest rate of lost-time claims in Canada (Kumar, 1991). Overexertion was the most common cause of injury (24.5% of injuries). The most frequent class of injury was sprains and strains (42.3% of injuries). However, when a non-monetary incentive was introduced there was a 50% reduction in the frequency of injury.

Similar results were found for construction workers by Hunting et al. (1994) when examining a surveillance database of injuries treated at an urban hospital emergency department in the USA. This was further corroborated by Hunting et al. (1999). Hispanics and labourers were found to be over-represented in the severe cases. This was interpreted as being associated with poor education and lack of training and perhaps also language barriers.

Welch et al. (1999) reported that, of construction workers who had had acute musculoskeletal injuries, almost half had on-going symptoms two months later and 40% had symptoms 12 months after the injury. Those who reported chronic symptoms also reported that their quality of life was substantially affected. Also only a minority of those injured had their jobs accommodated to their symptoms. Symptoms that persisted more than two months varied according to body part affected. Knee, leg, groin and hip injuries were most likely to last beyond two months followed by shoulder, neck and low back problems. Foot and ankle injuries and upper extremity injuries recovered the most rapidly.
The back is the body part most frequently injured in the construction industry and the major cause of injury was found to be overexertion (Kisner and Fosbroke 1994). Low back pain caused by musculoskeletal disorders has been estimated to afflict one third of construction workers at some time during their employment period (Holmstrom et al., 1992). Guo et al. (1995) showed that back pain is a major cause of morbidity and lost production work in the USA with carpenters being at high risk. Shirai et al. (1998) found a clear association in construction workers between the prevalence of low back pain and a history of low back pain and stiffness of the shoulder. Construction is in the top four high-risk occupations in the USA for carpal tunnel syndrome (Tanaka et al., 1995).

Eva et al. (1992) showed that the levels of disability of construction workers receiving disability pensions due to musculoskeletal disorders were greater than for other occupations since they were likely to be affected in four body regions (low back, neck/shoulder, hip and knee), whereas the other occupations were likely to be affected in only two or three regions.

1.3. Effects of a previous history of medical problems

Musculoskeletal symptoms cannot always be clearly attributed to either an acute or chronic stress, but rather a combination of them both; which may lead to difficulties in defining the population at risk for CTDs as well as a problem in addressing risk reduction (Hunting et al. 1994). Therefore medical / symptom / injury histories need to be carefully collected, especially since subjects do not consistently report previous injuries and their reports may include injuries resulting from both acute trauma and chronic stresses (Hunting et al., 1994).

1.4. Specific risk factors for WMSDs

1.4.1. Age

In Germany demographic changes and loss of interest of young people in a career in the construction industry will lead towards an increase in the proportion of older workers (Arndt et al. 1996). It is therefore important to evaluate the related risk of disability of older construction workers.

Petersen and Zwerling (1998) found that older construction workers (51-61 years) are more susceptible to musculoskeletal problems and emotional/psychiatric disorders when compared with their counterparts in other occupations. Older construction workers were 1.4 times more likely to suffer back problems and 1.3 times more likely to have foot or leg problems than blue collar workers, and 1.7 times more likely to have been diagnosed with an emotional problem than other blue-collar workers. Bye’s (1991) comparison of different age groups in two occupations revealed that carpenters between 30 and 40 years were ten times more likely to have musculoskeletal disorders in their arms or hands, than office workers of the same age.

Welch et al. (1999) found that older construction workers were more likely then younger co-workers to have continuing symptoms of musculoskeletal injuries as a result of musculoskeletal injury. According to Holmström et al. (1992b), age was significantly related to low back pain, but no clear association was found with increased age in the older age group (>50 years). However, this could be interpreted as a healthy worker effect since the younger (< 30 years) and the middle age group (30-49 years), did show an association with increased age.
Age is also a prominent risk factor for neck/shoulder trouble and considerable neck/shoulder pain in construction workers (Holmström et al., 1992a). Viikari-Juntura et al. (1994) also found age to be a predictor for contracting severe neck trouble along with dynamic physical work.

1.4.2. Obesity

A comparison of carpenters and plasterers with white collar workers showed that they had a higher body mass index, i.e., they were more obese (Arndt et al., 1996).

1.4.3. Smoking / alcohol consumption

Over half of construction workers were found to drink alcohol and smoke cigarettes on a daily basis. The proportions of white collar worker doing so were much smaller (Arndt et al., 1996). A weak relationship between smoking and neck/shoulder trouble and neck shoulder pain was found amongst construction workers (Holmström et al., 1992a).

Current smoking was found to be a predictor for contracting severe neck trouble along with dynamic physical work (Viikari-Juntura et al., 1994, Takala et al., 1992). Also, a study of twins showed more degenerative changes in magnetic resonance images of the lumber spine in the twins that smoked than the non-smoking twins (Battie et al., 1991). Rothenbacher et al. (1989) showed an association between early retirement and cigarette smoking amongst construction workers. Riihimaki et al. (1994) associated smoking with an increase in the risk of sciatic pain, but only in blue collar workers.

1.4.4. Gender

According to Goldenhar and Sweeney (1996) health research on female construction workers is virtually non-existent. In 1990, females made up approximately 2% of the construction work force in the USA (US Bureau of the Census, 1990). The major concerns of females in the construction trade with regard to musculoskeletal disorders are injuries to the back sustained while lifting, bending and twisting. Also of great concern to the women, were their lack of education, training, and equal opportunities compared to male co-workers. The main gender-related issues they were concerned with were the lack of protective clothing and tools designed to fit women, the need to be seen to be as capable as male colleagues, the lack of washing facilities and psychosocial stressors.

1.4.5. Physical work load and exposure to lifting / twisting

Many basic ergonomic principles for material manual handling (MMH) are ignored according to Ciriello et al. (1999). Their study revealed that 31% of the insurance costs paid by the insurance companies due to manual handling were in the construction, trucking and service industries. Therefore, job redesign strategies should be focused towards decreasing loads of lifts, lowers and carries, minimising hand distances, increasing heights of start lifts and decreasing distances of pushes, pulls and carries, and decreasing frequencies of lifts, plus an effort to decrease the number of lifts and lowers.
Material handling more often than once every five minutes, and work with the hands above shoulder level, were found to be the most significant contributing factor in neck/shoulder trouble and neck/shoulder pain (Holmström et al., 1992a). Viikari-Juntura et al. (1994) indicated that dynamic physical work was associated with the risk of persistently severe neck trouble.

Jobs involving repetitive motions of the hand contribute disproportionately to a number of injuries and illnesses. Analysis of data from workers’ compensation claims (the equivalent of UK sickness benefits) showed that construction workers were in the occupations most at risk. However, it must be stressed that a number of cases are underreported, which could be due to workers failing to recognise the causal relationship between their activity and their symptoms (Jensen et al., 1983).

### 1.4.6. Organisational factors

The variable nature of the construction industry, where manual handling exposures (and site conditions) are constantly changing as projects progress, and the chronic nature of WMSDs combine to produce a situation where it is difficult to implement effective interventions to reduce the risks of WMSDs. Paradoxically, safety incentive programs where employees are rewarded for a set amount of days without loss of time for a work-related accident may encourage workers to underreport illnesses and injuries and then continue working with discomfort and pain, only to exacerbate their condition, possibly leading to permanent disability (Schneider et al., 1995).

Factors such as whole body vibration when operating construction equipment are associated with high risks for back problems. Since this type of WMSD is often cumulative, and the workers frequently change jobs, contractors have little incentive to make changes to the cabs of construction equipment. Unless the workers are currently experiencing problems, contractors do not recognise the need to make changes.

### 1.4.7. Psychosocial factors

Construction workers believe that getting hurt and working with pain are part of the job. Injured workers prefer to work, even with restrictions, finding alternative ways to perform tasks if in pain. Construction workers claim that effects of serious work-related injuries reach beyond just the physical symptoms with long term financial and emotional effects to the worker and their families (Welch et al., 1999). Holmström et al. (1992a) reported that 21% of construction workers experienced a high degree of stress. Significant increases in reports of neck/shoulder trouble and neck/shoulder pain were found amongst construction workers with high levels of psychosomatic and psychic indices; stress, quantitative demands and experience of frequent anxiety about health were also significant. Low levels of job satisfaction were also related to increased reporting of trouble and pain in these areas of the body.

More suicides were observed in semiskilled construction workers in a comparative study with warehouse workers and semiskilled workers (Damlund et al., 1982).

Holmström et al. (1992a) found over half of their sample of construction workers reported low back pain in the previous year, and 7% complained of severe low back pain. A
dose-response relationship was found between severe low back pain and stooping and kneeling. Back pain was reported more by those who reported high degrees of stress.

Many authors have found a relationship between psychosocial factors and musculoskeletal disorders. It is postulated that anxiety, nervousness and mental strain increase static muscle activity and provoke pain (Holmström et al., 1992, 1993). Therefore, any changes proposed to reduce the risks of WMSDs must consider the organisational and psychosocial factors, such as pay, job security, subcontracting, and the number of hours worked, etc.

1.4.8. Other risk factors

Other risk factors include occupational and ergonomic factors, such as the sum of lifted tonnes during the working life, whole body and hand-arm vibration, and the length of time spent in manual work.

1.5. Available observational methodologies for studying ergonomic risk factors in construction

Construction work can be non-repetitive in nature, with job tasks being non-cyclical and can consist of long or irregular cycles, which can make it sometimes difficult to study. The most common observational techniques used to examine ergonomic exposures are based on time-study or work sampling. Time-study based methods (e.g., Armstrong et al., 1982; Keyserling, 1986) create continuous or semi-continuous posture and occasional force level data. Work sampling involves observation of worker(s) at random or fixed, usually infrequent time intervals which are usually more appropriate for non-repetitive work.

PATH (Posture, Activity, Tools and Handling) is a work sampling based approach, developed to characterise the ergonomic hazards of construction and other non-repetitive work (Buchholz et al. (1996)) The posture codes in PATH are based on the Ovako Work posture Analysing System (OWAS) with additional codes included describing work activity, tools used, loads handled and grasp type. Observations are stratified by construction stage and type of operation for heavy highway construction.

There are a number of steps involved in using the PATH method: It starts with making contact with the site and performing a site walkthrough. The goal is to describe each stage of construction as a sequence of operations that can be broken down by the tasks and trades involved in each. The next stage is to meet a crew of workers to interview them and gain informed consent for the study. Preparation for data collection can then be piloted by weighing tools and materials being handled, customising data collection sheets, and checking inter-observer agreement. The main sampling can then occur while important aspects are videotaped or photographed to allow documentation and later analysis to occur.

2. EXISTING HSE DATA ON WMSDS IN THE CONSTRUCTION INDUSTRY

The HSE version of the Nordic Musculoskeletal Questionnaire (NMQ) (Dickinson et al., 1992) was used to collect data on the annual and weekly prevalences of musculoskeletal trouble and annual disability among 497 construction workers employed in twelve trades
(Francis, 1994). The data had been used to identify that bricklayers, plasterers and carpenters were the trades with the highest annual prevalences of musculoskeletal trouble.

Table 1. Construction trades NMQ data were collected from

<table>
<thead>
<tr>
<th>Trade</th>
<th>Abbreviation</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>AD</td>
<td>31</td>
</tr>
<tr>
<td>Bricklayers</td>
<td>BL</td>
<td>127</td>
</tr>
<tr>
<td>Carpenters</td>
<td>CA</td>
<td>78</td>
</tr>
<tr>
<td>Electricians</td>
<td>EL</td>
<td>19</td>
</tr>
<tr>
<td>General Labourers</td>
<td>GL</td>
<td>88</td>
</tr>
<tr>
<td>Ground Workers</td>
<td>GW</td>
<td>44</td>
</tr>
<tr>
<td>Painters</td>
<td>PA</td>
<td>10</td>
</tr>
<tr>
<td>Plasterers</td>
<td>PL</td>
<td>29</td>
</tr>
<tr>
<td>Plant operators</td>
<td>POPS</td>
<td>13</td>
</tr>
<tr>
<td>Plumbers</td>
<td>PU</td>
<td>22</td>
</tr>
<tr>
<td>Roofers</td>
<td>RO</td>
<td>15</td>
</tr>
<tr>
<td>Scaffolders</td>
<td>SCA</td>
<td>24</td>
</tr>
<tr>
<td>EL + PA + POPS + PU + RO + SCA</td>
<td>‘Others’</td>
<td>103</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td>497</td>
</tr>
</tbody>
</table>

Inevitably there were differences in the numbers of responses from the different trades. For the purposes of this study all trades with fewer than 25 responses were grouped together into a single category labelled ‘Others’. Figures 1, 2 and 3 show the reporting rates for annual prevalence, weekly prevalence and annual disability for the nine regions of the body of the seven groups of workers.

As can be seen from the graphs, there is no clear differentiation between the different trades in terms of reported problems and the relative rates of problems vary between body parts. Thus, bricklayers report the greatest annual prevalence for trouble in the wrists/hands but the second lowest prevalence in the knees, and plasterers report the greatest levels of problems in the upper back but the least in the ankles. It is therefore likely that the differing demands of the different trades are causing these differences between trades in the patterns and frequencies of reports of musculoskeletal trouble.

Two conclusions follow from these figures: Firstly, the three trades under consideration in this report should not be seen as very significantly worse than other construction trades, as all construction trades are physically demanding to a certain extent. Secondly, because of the differences in patterns of reports of ‘trouble’ between different trades, solutions must be trade-specific. In other words, there is no single intervention to reduce the risks of musculoskeletal disorders that can be applied wholesale across the construction industry.
Figure 1. Prevalence of musculoskeletal ‘trouble’ within the previous 12 months
Figure 2. Prevalence of musculoskeletal ‘trouble’ within the previous 7 days
Figure 3. Prevalence of disability within the previous 12 months due to musculoskeletal ‘trouble’
3. BRICKLAYERS

3.1. Prevalence of musculoskeletal disorders in bricklayers

Akinomayowa (1987) reported a large study of Nigerian bricklayers. Medical records of 6500 were reviewed, and 97% were found to be suffering from musculoskeletal disorders, with severity increasing with age. Rural bricklayers had a significantly higher prevalence than urban dwellers. Younger subjects had problems confined to the upper limb and the legs. Older workers were more likely to have low back pain.

Heuer et al. (1996) reported a cross-sectional study of 195 German bricklayers who underwent a clinical examination to detect musculoskeletal complaints and functional impairments. Complaints and impairments increased with age, but the analysis did not reveal a positive association between musculoskeletal problems and length of employment. Instead, a ‘healthy worker’ (‘survivor’) effect was revealed when pairs of bricklayers of the same age were compared, with decreases in complaints and impairments as length of employment increased. The bricklayers who had entered the trade later in their working career were more likely, above the age of 40, to drop out for health reasons, suggesting differences between ‘early’ and ‘late’ bricklayers in susceptibility to musculoskeletal problems, particularly in the low back.

A German study of construction workers had the prior hypothesis that ‘repetitive strain in forced positions during a long period of time is a risk factor for LBP [low back pain] and LBD [low back disability]’ (Sturmer et al., 1997). They noted that bricklaying is characterised by inclined work postures and by lifting and carrying bricks weighing 5-24 kg at 100 times per hour. They therefore carried out an analysis of cross-sectional data from a baseline interview and physical examination from a prospective cohort study of 571 male construction workers. Bricklayers with more than 10 year’s experience were found to have more clinical signs of low back disorders than other construction workers. This was not seen for other job categories, including carpenters. Sturmer et al. (1997) argued that this indicated a potential for prevention of LBD in people working as bricklayers for prolonged periods. Bricklayer’s tasks were found to be characterised by a large proportion (approximately 50%) of very repetitive tasks performed under load, unlike the tasks of house painters, carpenters and concrete builders.

Latza et al. (2000) used the longitudinal phase of this study to identify risk factors for LBP among construction workers. 230 workers from a variety of trades who initially reported being free of LBP were followed up after three years and 30.9% reported LBP within the last 12 months of this period. The risk of back pain was more than doubled in carpenters who reported sawing wood for up to an hour per shift and in bricklayers who reported spending more than two hours per shift laying large sandstones.

3.2. Block handling

Blocks used in constructing interior walls in the Netherlands are made of gypsum and are laid by a specialised group of workers (van der Molen et al., 1998). They weigh 23 or 25 kg and measure 670 mm × 500 mm × 70 mm.
van der Molen et al. (1993) listed recommended solutions to diminish the physical workload of workers laying gypsum blocks. These solutions had been further developed and tested in ‘participatory ergonomics’ projects at company level:

- Use mechanical means of transport to diminish transport handling;
- Diminish the weight of the gypsum blocks to less than 18 kg;
- Diminish the workload by alternating lighter and heavier tasks, such as building and finishing tasks.

3.2.1. Mechanisation

van der Molen (1998) reported that using a hydraulic crane to transport bricks from the storage site into the house, and using a small trolley to carry and lift the bricks in the house eliminated most of the manual transportation of the blocks. Another device used for placing bricks in the wall caused awkward working postures and lower productivity than manual lifting and positioning of the bricks. Time savings of four days per house were found, with reduced costs.

3.2.2. Job enlargement

The tasks of a team of two gypsum bricklayers were enlarged by giving them the other tasks associated with internal walls to carry out (van der Molen et al., 1998). The additional tasks were “setting profiles”, “outlining electric wires”, “filling gaps”, installing electric wires and plastering. This reduced the daily number of bricks handled by over 50% and reduced the total time to construct interior walls in a house from seven days to one day. However, the bricklayers were sceptical about the task enlargement.

3.2.3. Reducing block size and weight

Brouwer et al. (1991) carried out a laboratory study to examine the effect of lowering the mass and reducing the size of gypsum bricks. Bricks were either normal or half size and either the normal density or hollowed to reduce the weight by 30%. Reducing the mass reduced the mechanical load on the spine and the physiological cost by lowering the heart rate. Reducing the size also reduced the biomechanical load and the heart rate but also extended the construction time significantly. Therefore, it was recommended that lighter bricks of the original size should be used. In a follow-up on-site project 500 × 500 × 70 mm blocks weighing less than 18 kg were used (van der Molen, 1998). Hardly any adverse effects on efficiency were observed and the workers were generally positive about these bricks.

van der Molen and Veenstra (2000) list measures recommended by Arbouw in the Netherlands to reduce the physical workload of bricklayers. These included technical changes to improve scaffolding systems, provide raised platforms and tables for placing materials, and reduce block weights to less than 4 kg and restrict their maximum width to 105 mm; organisational methods such as implementing improved work-rest schedules and task enlargement and task rotation; and individual measures such as providing information and training and personal protective equipment.
3.2.4. **Provision of hand grips on blocks**

Vi *et al.* (2000) examined the handling of concrete cellular blocks weighing 20 kg with and without the addition of a handle or hand grip to the block. They found that when a handle was added, the peak trunk angle, and trunk moments were significantly lowered. They attributed this to the handles allowing the workers to lift the blocks close to the body thus reducing the trunk angle and the loading on the low back and therefore reducing the risk of low back injury.

3.3. **Physical fitness**

Astrand (1967) measured working heart rates of a sample of 10 bricklayers, 9 carpenters and 14 labourers. She found that the bricklayers and labourers had a slightly lower heart rate at submaximal work intensities than the average Stockholm males and a slightly higher heart rate than men who were moderately active. The carpenters were similar to the average Stockholm male. However, there were large intra-sample variations. The implication is that the bricklayers and labourers were between the average male and moderately active males in physical fitness and that carpenters were less fit.

3.4. **Physiological and biomechanical workload**

Bulthuis *et al.* (1991) measured heart rate and oxygen consumption and recorded postures of Dutch bricklayers building internal walls using 23 kg gypsum blocks 67 × 50 × 7 cm. They spent 43% of their time actually building walls, 21% finishing the walls, resting for 17% and carrying out preparation work for 19%. The mean working heart rate was 110 bpm and the mean heart rate while actually building walls was 111 bpm. Oxygen consumption during building walls was 1.41 litres per min. 26% of posture observations recorded trunk flexion. In 10% of observations, trunk flexion was greater than 75°. Only 4% of observations involved trunk rotation or lateral flexion. In 21% of observations, blocks were being handled.

They concluded that the oxygen consumption exceeded a recommended limit of 1.06 litres per min for an eight hour day. The working heart rate varied between 53% and 65% of maximum; the widely accepted limit of 35% of maximum oxygen consumption corresponds to 55% of maximum heart rate. They concluded that the workload of gypsum bricklayers is high and the masses of the bricks and working postures affect the loading of the back.

3.5. **Fatigue**

Jorgensen *et al.* (1991) investigated whether signs of muscular fatigue could be found in the trunk extensor muscles of Danish bricklayers whose work is highly monotonous and repetitive, with frequent rotational and asymmetric loading of the lumbar spine. Mean spectral frequency of the paravertebral muscles decreased and the EMG amplitude increased over the working day, indicating the development of muscle fatigue, despite the subjects being physically fit.
3.6. Ergonomic improvements

Vink and Koningsveld (1990) sought to demonstrate that the working conditions of bricklayers could be improved. An experiment investigating the effect of placement of bricks and mortar showed that raising them to at least 0.3 m from the floor level appeared to lower the energy consumption especially when bricks were placed in the higher rows in the wall. Subjective ratings of load on the back were least for laying the upper rows of a wall with the bricks placed on a 0.5 m high platform, but the lowest overall load on the back was experienced when the bricks were placed on a 0.3 m high platform. Height adjustable scaffolding was found to be available but was only suitable for an ideal building site on level ground, and with straight walls.

Koningsveld and van der Molen (1997) described a series of improvements made to the bricklaying task in Holland. Brick packs were redesigned so that each pack could be split from 400 4 kg bricks down to 200s, 100s or 50s. Handling tools for each size of pack were introduced, including a specialised wheel barrow which could lift the stack electrically to place it on a trestle or console at a height of 0.5 m. Mortar could be brought to the bricklayer by being pumped to the working position. These changes reduced the biomechanical load by 30% and were viewed positively by the bricklayers. They did require systematic planning to operate on a site, but produced increases of productivity of 15% by the bricklayers and required fewer workers to supply the bricks.

Clery (1990) reported a Dutch project that had developed a system where the mortar used in bricklaying was applied by being pumped from a tank. This led to narrower gaps between the layers of bricks and increased the rate at which bricks could be laid.

3.7. Workplace layout

In the USA, Stino and Everett (1998) examined, in a small sample of ‘masons’, the effect of changing the workplace layout on the productivity and the ergonomic implications of bricklaying. The low back, shoulders and elbows appeared to be the regions with notable musculoskeletal problems. The wall heights associated with least and most discomfort were ‘wrists/hands to elbows’ and ‘ankles/feet to knees’, respectively. These regions were also respectively the quickest and slowest levels to build. Also, most of the masons preferred to have the material supply at the ‘wrist/hand’ level.

4. CARPENTERS

4.1. Prevalence of musculoskeletal disorders in carpenters

The largest single cause of three-day accidents reported under RIDDOR 95 by the UK woodworking industry in 1997 and 1998 was manual handling and the most common injuries were strains. These account for approximately 30% of the reported accidents.

Employment in carpentry requires the use of different body parts and, depending on the task, may require forceful use of the back and upper and lower limbs. Such work often entails the handling of power tools, or forceful repetitive gripping, twisting, reaching or moving actions.
Work may occur in confined spaces or awkward positions, such as with the arms raised above shoulder level, or with awkward postures of the shoulder, arm and wrist.

Franklin et al. (1991) cite data from the US Bureau of Labor Statistics showing that occupational injury rates among carpenters employed in construction are high compared to rates in the general work force in the USA. They also state that a major cost of lost work days and workers’ compensation in the United States is occupational carpal tunnel syndrome, and the highest industry rates were found amongst carpentry, wood products and logging.

Carpenters and plasterers were found to have a higher prevalence of musculoskeletal abnormalities than white collar workers (Arndt et al., 1996; Brage et al., 1997). Carpentry, and the food processing industry, were found to have the highest incidence of occupational carpal tunnel syndrome in a comparison of a range of industries (Franklin et al., 1991).

Sciatic pain was more common among carpenters and machine operators than office workers, but occupational differences were considerably smaller with regard to non-specific low back pain and lumbago. Working in twisted or bent postures, as well as machine operating and severe back accidents, were risk factors for sciatica (Riihimaki et al., 1989). Riihimaki et al. (1994) examined the incidence of sciatic pain among men in three different occupations: machine operating, dynamic physical (carpentry) and sedentary (office work). They found it was highest among carpenters and machine operators. In addition, the prevalence of sciatica was related to age, previous history of back accidents and working in bent or twisted postures.

A cross-sectional study (Luoma et al., 1998) of the risk factors for lumbar disc degeneration in various occupations showed an increase in posterior disk bulges amongst carpenters. Also, sciatic pain was more common among carpenters and machine operators than among office workers. Another Swedish study (Holmström et al., 1991) highlighted the fact that early retirements due to musculoskeletal disorders were more common in construction workers (including carpenters) than other occupations. During 1988-1989, 72% of all sick leave over four weeks in the construction industry in Sweden was due to musculoskeletal disorders.

As a note of caution, it is apparent in the literature that the ways in which data are presently collected are not always comparable or consistent. Thus hospitals and insurance companies record data on back pain cases and insurance claims in different ways. It is therefore essential that carefully documented work histories and medical histories are recorded as part of the health examinations of construction workers in order to achieve the best potential in preventing occupational and chronic diseases.

Lemasters et al. (1998) recommended that a longitudinal study be carried out starting at the time of entry into the carpentry trade to gain a better understanding of the injury risks and predictive factors related to leaving or staying in carpentry.

Risk factors for neck and shoulder problems include static muscle activity, short work cycle time, elevation of the arms or shoulders and flexion/rotation of the head in relation to the spine. Also, awkward postures are adopted during some manual handling.
4.2. Formwork

‘Formwork’ is a general term used to describe the creation of the variety of moulding systems used in concrete construction. The ergonomic hazards associated with it depend on the system being used. They mostly involve cutting of vertical plywood panels using electrical power saws. The saws used are generally heavy (approximately 8.6 kg) and are poorly balanced from an ergonomic perspective, with the weight being concentrated in the front handle. The way in which these heavy saws are used may increase the amount of force required and therefore increase the stress on the musculoskeletal system. Carpenters may also need to exert a great deal of force when breaking the bond between concrete and plywood when the formwork is dismantled. The use of sledge hammers is liable to create a strain on the back, and also lead to impact shock to the lower arm, wrist and hand.

Welch et al. (2000) found that carpenters carrying out formwork had more strains and sprains (40% of injuries) and fewer lacerations (24% of injuries) than carpenters carrying out other tasks (16.6% and 52%).

4.3. House building tasks

Mirka et al. (2000) reported ergonomic interventions tested on carpenters building timber-framed houses in the USA. They identified erecting pre-assembled exterior and interior walls, moving timber from ground level to higher stories and continuous use of nail guns at floor level as being high risk tasks. They found that providing a pneumatic lift to lift the wall frames to near the upright position reduced the load on the back and workers felt it was worth the extra time that it took to use it. Provision of a motorised hoist reduced the manual handling needed to lift materials to higher levels and increased productivity. Provision of a nail gun extension eliminated the need for crouching and stooping when nailing floors and 75% of workers felt that their productivity using it would increase with experience.

4.4. Trimming / ‘snagging’ work

These tasks are performed at the end of a project to ensure that all final minor problems and defects have been dealt with. It usually involves awkward postures, and also much kneeling. Hanging doors can also place considerable strain on the back muscles, while aligning the hinges, trimmings, etc.

4.5. Use of hand held tools

Ergonomic issues can be related to three factors when using either hand or powered tools such as saws, sanders, hammers, or staple guns: Firstly, the tool itself must be gripped and lined up with the task, at the correct orientation. Secondly, the materials may require support during the process (generally on a non-adjustable assembly platform). Thirdly, the nature of the product and the manufacturing process, can contribute to postural strain. Good tool design can help reduce the loading on the body by providing a comfortable hand grip, low vibration and low shock loading.
4.6. Postures adopted by carpenters

4.6.1. Posture classification

A checklist (Table 2 and Figure 4) for assessing the postures that a carpenter adopts during work has been developed by Bhattacharya et al. (1997). In the checklist each posture is assigned a score from 1 to 5 where a score of 1 is the least stressful or most natural posture and a score of 5 indicates a very poor, unnatural (biomechanically most stressful) posture. Thus the higher the score the more physically demanding the posture is, and the harder it is to sustain for long periods. Weighting factors were also used to account for the repetitiveness of a task. For small groups of carpenters specialising in formwork, ceiling and drywalling the body parts with the worst scores were the neck/shoulder, the elbow, and the back. Formwork posed the highest risks for the hips/legs, back and elbows, and ceiling tasks were the most stressful for the neck/shoulder and wrist regions.

Table 2. Descriptions of postures and weightings in the ergonomic walkthrough checklist developed by Bhattacharya et al. (1997).*

<table>
<thead>
<tr>
<th>Weight</th>
<th>Neck / shoulders</th>
<th>Back</th>
<th>Elbow</th>
<th>Hip / legs</th>
<th>Wrist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Free and relaxed</td>
<td>Natural posture and well supported in seated and standing position</td>
<td>Natural posture and small demand on strength</td>
<td>Natural posture and well supported in seated and standing position</td>
<td>Wrist relaxed; no stress on joint</td>
</tr>
<tr>
<td>2</td>
<td>Natural posture but limited by work</td>
<td>Natural posture but limited by work</td>
<td>Arms slightly tense</td>
<td>Natural posture but limited by work</td>
<td>Slight force on joint</td>
</tr>
<tr>
<td>3</td>
<td>Tensed due to work</td>
<td>Bent and/or poorly twisted</td>
<td>Arms tense and/or joint in extreme position</td>
<td>Poorly supported; unsafe footing</td>
<td>Slight force on joint</td>
</tr>
<tr>
<td>4</td>
<td>Neck twisted, bent, arm above shoulder</td>
<td>Bent and twisted without support</td>
<td>Elbow elevated at &gt;30°; static work</td>
<td>Stand on one foot or kneeling or stooping</td>
<td>Pinch grip</td>
</tr>
<tr>
<td>5</td>
<td>Neck bent backwards, strength demand on arms</td>
<td>Bent over below waist and heavy work</td>
<td>Great demand for strength in the arms</td>
<td>Poor posture during heavy work</td>
<td>Wrist in extreme/awkward posture requiring excessive force</td>
</tr>
</tbody>
</table>

4.6.2. Kneeling

Jensen et al. (2000) found an increased prevalence of radiological signs of knee osteoarthritis among floorlayers (i.e., carpet fitters) but not among carpenters but that it was mostly found among workers older than 50. They concluded that the more knee-straining postures required by floorlayers seemed to be a more important risk factor than heavy physical work.

Figure 4. Posture classification in the ergonomic walkthrough checklist developed by Bhattacharya et al. (1997)*

5. **PLASTERERS**

5.1. **Introduction**

Plastering tasks can be divided into three areas:

1. **Traditional wet plastering** where a thick base coat and a thin skim coat are applied to the walls to be plastered; This would normally be done to brick or blockwork.

2. **Dry lining**, where sheets of plasterboard are attached to walls and ceilings and then given a skim coat of wet plaster. This would often be done over timber partitions to form internal walls. It has replaced lath and plaster techniques where thin strips of wood (laths) were nailed across partitions or ceiling rafters and then given a coat of plaster.

3. **Screeading of concrete floors**, i.e., applying a surface to the concrete base of a floor.

There is relatively little information in the ergonomics literature relating to plastering. What there is relates almost exclusively to dry lining tasks and has originated in North America and therefore refers to the building practices there which are not identical to UK techniques. Also, the terminology in the US is different as the phrases ‘dry wall’ and ‘drywalling’ are used in preference to ‘plasterboard’ and ‘dry lining’. Also, the workers who carry out drywalling are normally described as ‘specialist drywall installers’ or ‘carpenters’ (Pan et al., 1998, 1999a), whereas the workers who carry out sanding and finishing tasks are usually painters (Pan et al., 1999b, 2000a).

5.2. **Prevalence of musculoskeletal disorders in plasterers**

Hsiao and Stanevich report that, in 1987, 1.41% of workers (70,510) in the US construction industry were employed as drywall installers and that their compensable injury rate of 27.5 cases per 100 workers was three times the mean rate of 9.5 cases per 100 workers for the whole construction industry. Overexertion (28%), fall from height (24.7%) and being struck by an object (15.1%) were the leading types of injury.

Chiou et al. (1997) sought to identify the risk factors associated with drywall installation through analysis of the characteristics of traumatic injuries suffered by drywall installers in the USA. They estimated incidence rates for lost workday traumatic injuries as 7.7 and 5.4 per 100 drywall installers in 1992 and 1993 respectively, with an average of 14.2 lost work days per traumatic injury. 42.9% of injuries were sprains, strains and tears, 12.2% were fractures, and 11.1% were cuts and lacerations. 26.9% of injuries were back injuries, and the most common event was overexertion (22.1% of injuries). 32.2% of trunk injuries were related to handling of solid building materials, and 31.9% of trunk injuries resulted from overexertion in lifting. More overexertion cases occurred during lifting (13.8%) than carrying tasks (4.5%), which may reflect the use of mechanical means to transport drywall sheets. Overexertion injuries resulted in a mean of 13.3 lost work days while falls to a lower level resulted in a mean of 19.6 lost work days.
Chiou et al. (2000) examined data on traumatic injuries suffered by drywall installers that resulted in at least one day away from work. These data were obtained from the US Bureau of Labor Statistics and covered the period from 1992 to 1995. There were a total of 16023 recorded cases over this period but the rates decreased from 4680 in 1992 to 3065 in 1995. Half of these injuries resulted in at least 8 day’s absence and a quarter resulted in at least a month’s absence. 45% of injuries were to muscles, tendons, ligaments or joints. Overexertion while lifting resulted in 16% of the total injuries. 60% of injuries to muscles, tendons, ligaments and joints affected the trunk, and 36% of trunk injuries resulted from overexertion in lifting. The trunk injuries were most likely to be associated with the handling of solid building materials (32%), especially drywall.

They concluded that, because the injuries were similar to those suffered by other construction workers but the sources of injury were different, then intervention strategies should be implemented on an occupation and task-specific basis. They suggested that intervention strategies for drywall installers should focus on tasks, such as hanging drywall sheets onto the ceiling, that are likely to cause sprains and strains during free-body movements.

Lipscomb et al. (2000) examined worker’s compensation claims made by drywall installers in western Washington State between 1989 and 1995. Of 1773 drywall installers, 1046 filed 2567 claims. 230 claims by 203 individuals resulted in at least three months of paid lost time. ‘Sheetrock’ (i.e., plasterboard) was associated with more than 25% of the more serious injuries. 41% of overexertion injuries were due to lifting.

The claims of this group of workers were 25% higher than for the cohort of all union carpenters in the same area. It was a very young cohort with little union experience, indicating that many workers do not stay in the trade for long periods of time. Claims where plasterboard was identified as the object associated with injury accounted for about 30% of costs. Lipscomb et al. (2000) concluded that the lack of pattern of injury due to age or experience probably reflected the heavy nature of all drywall work and that ergonomic solutions to alleviate the physical demands on these workers are needed.

There appears to be no information available within the ergonomics literature on prevalence of musculoskeletal disorders among workers carrying out wet plastering except Hsiao and Stanevich (1996) who reported that plasterers in the USA had 22.9 compensable injuries per 100 workers.

Also, no literature was located which deals with the musculoskeletal problems of workers laying floor screeds. There is literature related to the problems suffered by carpet installers but this is usually related to the use of knee kickers to tension carpets while they are being fitted.

5.3. Plasterboard Tasks

Installation of plasterboard requires manual handling operations involving lifting, carrying and supporting. Often these operations must be carried out in confined spaces, particularly in the construction of housing where passages and doorways are relatively narrow. In the UK, plasterboard comes in a variety of size sheets, which are typically 9.5 mm, 12.5 mm or 15 mm thick. Usual widths are 1200 mm and 900 mm and lengths range between 1800 mm and 3000
mm in 300 mm steps. The density of standard boards is in the region of 680 kg/m³ giving weights per square metre of 6.5 kg, 8.5 kg and 10 kg for 9.5, 12.5 and 15 mm thick boards respectively, (data derived from figures on the British Gypsum website). Thus a typical 12.5 mm × 1200 mm × 2400 mm board will weigh approximately 24.5 kg, a smaller 12.5 mm × 900 mm × 2400 mm board will weigh 18.4 kg, and a 15 mm × 1200 mm × 3000 mm board will weigh 36 kg. There is also a variety of specialist boards with additional fire-resistance, vapour resistance or insulation properties, but these are largely of similar densities. Smaller and thinner boards tend to be used for ceilings because of the need to lift them and hold them in position while they are being fixed. Pan and Chiou quote sizes of drywall in the USA as being 51 lb to 109 lb (23 kg to 49.5 kg) weight, typically 4’ (1220 mm) wide and 8’ to 16’ (2440 mm to 4880 mm) long and 3/8” to 5/8” (9.5 to 16 mm) thick.

Pan and Chiou (1999) identified four different methods of handling sheets of drywall (Figure 5). Lifting a vertical sheet accounted for 40% of the lifts they observe; lifting with both hands on the top of a horizontal sheet accounted for 7%; lifting with both hands on the lower edge of a horizontal sheet accounted for 23%, and lifting with one hand at the top and one at the bottom of a horizontal sheet accounted for 30%. Using a static biomechanical model they estimated that 92 to 93% of male industrial workers would be able to lift a sheet weighing 27 kg using the first three methods but only 83% would be able to lift it with the fourth method. If the sheet weight increased to 45 kg only 53% to 62% would be able to lift it with Methods 1 to 3, and the percentage capable of lifting it with Method 4 would drop as low as 36%. They therefore concluded that all four methods of lifting drywall sheets create overexertion hazards among construction workers and that the fourth method was the most stressful.

![Figure 5. Methods of lifting sheets of plasterboard identified by Pan and Chiou (1999)*](image)

There are two possible orientations for sheets being fixed to walls: either vertical or horizontal. Where the building has been designed so that the wall height matches the length of the board the boards will be installed vertically since only the final board being installed on a wall will need cutting and then only to width. This method allows the worker to grip the middle of the board in an upright posture at about chest height while moving it into position and allows it to rest on the floor while first being fixed into position (Method 1 in Figure 5). In this situation all the joints between boards are vertical.

When boards are installed horizontally two or three boards, depending on the board width and the wall height, will be fixed up the wall, starting at the bottom and working upwards. While the lowest board can rest on the floor while it is fixed, this will require stooping or crouching. Subsequent boards will have to be lifted above the lower board, holding either the top and bottom of the board, or with both hands holding one edge of the board (Methods 2 and 3 in Figure 5). Holding the top and bottom will induce twisted postures (Method 4 in Figure 5) and put most of the load onto the lower hand, and holding with both hands on one edge will decrease the amount of control possible. Depending on the lengths of the boards and the walls they are being fixed to, there may be vertical joints between boards if they are not long enough to cover the full length of the wall.

Lappalainen et al. (1998) reported a pilot study which examined the effect of the width of plasterboard sheets on the ease of manual handling. Ten experienced workers repeatedly carried a 1200 × 2600 mm board weighing 28.6 kg and a 900 × 2600 mm board weighing 21.7 kg 21 m across a clear floor in an industrial building. The subjects perceived the strain to be 40 to 50% less in different parts of the body while handling the lighter board and felt that it improved their postures. Also, because it was narrower they were able to see over the board more easily and felt it would be easier to manoeuvre in confined spaces. With one exception, the workers were strongly in favour of the 900 mm board due to its lighter weight and greater ease of handling. However, this use of smaller boards increases the number of fastenings required, and the number of joints to be taped.

Pan et al. (1998, 1999a) found that experienced carpenters rated the hazards (physical stress, fall potential and risk of being struck by or against objects) of hanging drywall on the ceiling as greater than those of hanging it on the upper and lower parts of a wall. In particular, lifting / carrying / holding drywall in an overhead position was perceived as producing the most physical stress. Also, the neck and trunk were found to be constantly in extension due to the need for overhead reaching when performing this task. Ascending onto scaffolding or stilts to hang drywall on the ceiling was perceived as having the greatest fall potential. The physical stress associated with using stilts was significantly greater than that associated with scaffolding or step ladders.

In the UK it is normal for a thin surface coat of plaster to be skimmed over plasterboard to cover any imperfections and fixings and to provide the final surface which is decorated. It appears that a less common practice is for joints between sheets of drywall to be filled with tape and a filler compound, but it also appears that this is the more common practice in the USA. The joint compound is applied in several layers with a trowel and a paper tape is pressed into it with the trowel while it is still wet. After each layer of the filler has dried the surface of the joint is sanded down. Pan et al. (1999b, 2000a) found that hand-sanding of drywall joints is a stressful process involving numerous repetitive motions often carried out at great paces. They also found that applying the tape to joints and corners requires considerable amounts of wrist flexion and work over shoulder height.

Because of the need to reach the ceiling and the tops of the walls, some workers perform the taping and filling tasks while standing on stilts. They may also carry out sanding operations with a sander on a pole. The use of stilts increases the risk of falling from a height (Pan et al., 1999b, 2000a).
Pan et al. (2000b) examined the effects on postural stability of different techniques of lifting and hanging sheets of drywall. They found that a horizontal lift of a drywall sheet with both hands on the top edge (Method 2 in Figure 5) caused least postural sway and instability. However, horizontal hanging on a wall caused more postural sway and instability than vertical hanging. For hanging on a ceiling, vertical hanging caused more sway and instability than horizontal hanging. As Pan and Chiou (1999) had shown that only 7% of workers lifted with both hands on the top edge, Pan et al. (2000b) suggest this was due to the strength this method demands from the shoulders and arms. They concluded that the majority of workers have an increased risk of fall injury due to their decreased postural stability. They also suggested the greater sway and instability due to vertical hanging on the ceiling might be due to the method adopted requiring trunk asymmetry of 90°.

5.4. Floor screeding

While screeding was not observed, plasterers did comment on it when asked. It is seen as the worst task that a plasterer has to do. The major problems are seen as being related to the need for working at floor level, leading to constant bending and kneeling. Depending on the site, the actual screed may need to be brought into the room using a wheelbarrow. The actual spreading is seen as difficult because of the need to physically move a dense material to ensure the floor is evenly covered and the need for long forward reaches while in stooped or kneeling postures. However, it appears that wearing trousers with sewn in knee pads helps decrease knee discomfort and problems.

6. DISCUSSION OF LITERATURE REVIEW

6.1. Who is responsible for making ergonomics improvements in the construction industry?

Designers, architects, and project owners between them determine the materials, methods and procedures needed to complete a construction project. Their choices can influence the postures, repetitions, forces and working practices. Suppliers of materials can also affect the WMSD risk factors such as weight of load, type of packaging and delivery methods.

6.2. What is the future of ergonomics in building and construction?

Koningsveld and van der Molen (1997) gave an overview of ergonomic progress in building and construction in the Netherlands. They described the industry as conservative and the work as still physically straining and with traditional work organisation and working methods.

They commented that mechanisation had increased greatly, but that most hoisting and lifting equipment suffered from a lack of accuracy beyond 100 mm, so for exact positioning workers still have to apply manual force. They suggested that a reduction of manual lifting and carrying had resulted in less variety so that “repetition strain injuries” are a new hazard in several construction trades”. In other words, work division, i.e., specialisation, has resulted in monotonous, often repetitive jobs. However, construction work throws up many unexpected problems that require improvisation, skill and expertise on site and the “resulting discussions and puzzles are welcome breaks in physically straining jobs”.
6.3. Possible controls for ergonomic risk factors

Evidence thus shows that there is a high rate of ergonomic injuries within the construction industry, with a number of ergonomic hazards being identified. Hazard identification is the first step in assessment. The promotion of ergonomically designed tools, and the training of their use, according to their application is recommended.

According to Hsiao and Stanevich (1996), the following need to be addressed with regard to ergonomic applications in construction:

- Identification of occupation specific risk tasks and activities so that effective interventions can be developed.
- Systematic evaluation of existing injury prevention technologies to overcome the barriers to the use of these technologies.
- Improvement of biomechanical exposure assessment technologies to help identify risk factors.
- Improvement of instruction equipment and assistive devices to reduce work-related stress.
- Implementation of new technologies to evaluate and develop fall prevention systems that better protect construction workers.

The benefits of the application of ergonomic principles must be explained as studies show that ergonomic interventions can meet with some resistance among experienced workers. Urlings and Wortel (1991) found resistance from workers when an adjustable height platform was introduced in the Dutch building and construction industry, since workers had a negative attitude towards the ergonomic intervention.

Possible ‘engineering’ interventions are:

- Modify forcefulness, repetitiveness, awkwardness, vibration levels, physical pressures, or environmental extremities while performing a job.
- Redesign equipment and tools.

Possible ‘administrative’ interventions are:

- Rest breaks;
- Changing work organisation;
- Job design and work training.
Personal protective equipment should generally be used as a last resort or in combination with other controls, since it reduces risks less reliably than engineering and administrative controls.

### 6.4. Manual handling of materials

Lifting should be automated or mechanised where possible, and the effective use of carts, trolleys, dollies and powered lifts can do much to remove the need for lifting. Lifting aids such as levers or hoists are often helpful in reducing the load on the individual. For example, a simple device (an adjustable steel rod approximately 60-80 cm with a hook at one end and a handle at the other) to assist when lifting sheets of product, e.g., wooden boarding, helps to reduce the loading on the back and arms.

### 6.5. Tools

Hand-held power tools should be chosen with caution as they will not only influence the task the tool is intended to perform but also the operator's work situation and the working environment. Ergonomically designed tools can aid the user in adopting less awkward postures, give more control, i.e., secure grip, be appropriate for the task and appropriate for the user. The weight of a hand tool, and in particular a power tool, can pose limitations on the length of time that an operator can perform a task, and may also reduce the degree of accuracy that an operator can achieve.

Lappalainen et al. (1998) showed that a lighter and narrower plasterboard significantly affects the physical load and risk of musculoskeletal diseases among installation workers. However, they argued that full health benefits could only be achieved if the workers were also taught correct lifting and carrying techniques.

### 6.6. Job design

Short cycle times are known to be a causative factor in the incidence of musculoskeletal disorders. Where possible, short cycle times should be extended by, for example, increasing the number of different operations included in the cycle. Some studies have shown that micro pauses (short breaks) after tightening each screw, reduce stress and can lead to an increase in productivity. Concrete formwork construction has been identified as the area of greatest ergonomic risk in unionised carpentry. Improved work techniques and intervention strategies are currently being developed (Spielholz et al., 1998).

### 6.7. Training

A key factor, that has been identified in several studies, is the usefulness of including ergonomic awareness as part of woodworkers’ training and the need for this education to be ongoing. An ergonomics awareness education program developed by Albers et al. (1997) for apprentice carpenters in the USA was found to be successful in:

- Increasing apprentices carpenters’ awareness of WMSDs within carpentry and construction;
- Identifying potential WMSD risks;
Motivating apprentices to prevent WMSDs.

6.8. Ergonomic solutions

There is an increasing recognition that work-related musculoskeletal disorders are widespread and costly within the construction industry (Schneider et al., 1995). It is not unusual for ergonomics to be sold to industry as a means of increasing productivity and reducing injuries. However, this increase in productivity can also be a dilemma to the construction workers as it could lead to fewer numbers being employed.

Many devices are available that can reduce ergonomic hazards for the worker. Figure 6 shows the kinds of device that are available which provide adjustable heights for palletising tasks. Clearly care would need to be taken when using such devices to ensure that their use on construction sites was appropriate to the conditions.

Researchers in Sweden have developed a “drill stand” (Figure 7) to use for tools for overhead work by supporting them on the floor base.
A plasterboard lift (Figure 8) can be used when fixing ceilings to support the plasterboard, leaving the carpenter’s hands free to use tools to fix it.

Other tools can also be adapted for jobs that require the worker to adopt awkward positions. For example screw guns have been developed with swivel handles, which may allow for
dealing with difficult hand positions. The modification shown in Figure 9 provides a better hand grip for an air drill.

![Figure 9. Modification of drill](image)

Simple mechanical handling aids such as an adjustable length hook can make lifting of sheet materials much easier (Figure 10).

![Figure 10. Hook lifting device](image)
The use of foot levers during the hanging of doors, has been shown to reduce the amount of back strain. Devices also exist for the mechanical handling of doors, which raise and lower the door to the appropriate height.

An air operated lifting device operating as a hoist can be used to pick up products, and manoeuvre them to the required position (Figure 11). An air cylinder is incorporated which pushes the load into the required position. This has been found particular useful in the manoeuvring of timber containers, and has been found to decrease back injuries.

![Figure 11. An air operated lifting device](image-url)
7. RESULTS OF SITE VISITS

7.1. Plastering

Two sites where employees of a specialist plastering firm were working were visited. Both sites were residential developments. At the first site two-coat wet plastering of a base coat and a surface skim coat was being used over internal blockwork walls. At the second site, blockwork and timber partition walls were being lined with plasterboard which was then skimmed with a finishing coat of plaster.

Plastering was also observed at a large scale development of additional laboratory facilities for a pharmaceuticals firm. What was observed was surface polishing of a skim coat being carried out from scaffolding in a stairwell.

7.1.1. Traditional ‘two coat’ wet plastering

At this site a single plasterer was found to be working in a house on a development where a number of houses were being built. Normally he worked with another plasterer who on that day was off sick.

At the time of the visit the ceilings of the house had been lined with plasterboard. He was working upstairs on the landing applying a base coat to the blockwork of the walls. At that time there was no water or electricity supplies within the house. His raw materials were stored in stacks on the ground floor in the house (Figure 12a), having been delivered by pallet to the door of the house. He carried sacks of plaster upstairs as needed (Figure 12b) and used an electric stirrer to mix the contents of approximately 1.5 25 kg sacks of plaster with water in a large plastic tub in a room adjacent to the landing (Figure 13a). The mixer was powered by a 110 V supply from a portable generator located outside the house. He then used a shovel to transfer the wet plaster from the tub to a table (Figure 13b) from where he carried it on his plasterer’s hawk to the wall (Figure 14a).

Plastering is inevitably a heavy manual task because it involves transferring by hand large quantities of a wet and dense material to a wall or ceiling. For the whole wall to be plastered it is necessary to reach each part of it with the float that is spreading the plaster on the wall. This therefore requires reaching to head height and above (Figure 14b) and stooping to reach down to floor level (Figure 15). It may also involve standing on a platform or ‘hopup’ to permit access to more awkward areas (Figure 16). It also requires access to areas, such as walls above stair wells that are normally beyond reach in a finished building. In this case there was no rail or guard around the stairwell and the plasterer worked from a single plank across the stairwell (Figure 12a), sometimes using a milkcrate as a hopup from the plank.

Clearly, in this case, the worker was using items that were easily available without sufficient consideration being given to the hazards of falling down the stairwell that such a system created.

The process observed of applying a base coat of plaster involved repeatedly carrying plaster on the hawk from the table to the wall and then spreading it onto the wall using the float. Once an area of wall had been covered with wet plaster it was then smoothed with a long two-handled float to ensure that the coat was smooth and even (Figures 17 and 18).
The downstairs rooms of the house had higher ceilings than the upstairs rooms. The hopup in use upstairs consisted of a single milkcrate, while one observed in one of the downstairs rooms consisted of three milkcrates lashed together to create a two-step stairway, therefore giving a higher platform.

The worker observed that the biggest problems in plastering were caused by the system of jobs being tendered at a fixed price therefore encouraging workers to work as fast as possible to maximise their earnings and therefore to cut corners in terms of health and safety. He also observed that attitudes among site owners and foremen varied considerably, and therefore attitudes to health and safety and provision of work equipment and welfare facilities varied widely.

The manual handling aspects of the observed task were:

1. The manual handling of bags of plaster and buckets of water. Unless some kind of mechanical bulk delivery of pre-mixed plaster can be developed, such handling is inevitable. The general move in the construction industry from 50 kg bags to 25 kg bags reduces the risk of handling raw materials and gives workers more options in how they handle the bags.

2. Mixing of plaster can be carried out either manually or with a powered mixer (a ‘whisk’). Use of an electric mixer requires a suitable power supply. The method chosen may depend on the type of plastering and the consistency required since skimming will generally require smaller amounts and thinner mixes than base coats.

3. Spreading of plaster onto the walls is inevitably a manual task. The amount of wet plaster handled at any one time is limited by the size of the hawk and, up to that limit the worker can carry as little or as much as he chooses. When applying large amounts of plaster for a base coat, the worker will have to trade off loading the hawk heavily with more frequent trips back to his supply of wet plaster if he loads it more lightly. The other limiting factor will be the nature of the grip on the hawk and therefore the tendency of the hand and forearm to fatigue due to sustained loading. The actual spreading of the wet plaster will require sufficient strength, flexibility and endurance in, in particular, the wrist and the muscles acting across it. It should not be forgotten, however, that because of the wide variety of postures required to reach all the areas being plastered, strength, flexibility and endurance will be required in all other parts of the body.
Figure 12. a) Supply of 25 kg sacks of plaster; b) Carrying 25 kg sack of plaster

Figure 13. a) Mixing plaster with an electric stirrer; b) Shovelling plaster from mixing tub to table
Figure 14. a) Carrying plaster on hawk; b) Plastering of wall near ceiling

Figure 15. Plastering of wall near floor level
Figure 16. Plastering of wall above doorway

Figure 17. Tool for smoothing plaster
7.1.2. Drylining

The site where drylining was observed was visited in the afternoon of the day that the site where two-coat plastering was occurring was visited. The overall impression gained was that the site was much tidier, much busier and generally better organised. Plasterers were observed working in two houses: two were carrying out dry lining tasks on the ground floor of one house; in another house, two were carrying out skim-coating over dry lined walls and ceiling. In fact, on arrival one refused to talk to us; the other said that he had finished actually plastering for the day and suggested we return the following morning.

Sheets of plasterboard were located in a stack on a pallet outside the front door of the house (Figure 19); pallets of bags of plaster were located in the garage of the house. Carrying of sheets of plasterboard into the house was not observed; clearly the size and hence weight of the sheets will determine the number that are handled at once. The design of the house (in this case a standard domestic front door leading into a hall with stairs up to the first floor, and standard internal doorways) will affect the amount of room available in which to manoeuvre sheets of plasterboard 2.4 m long and 1.2 m wide. This will therefore affect the risks of handling of such sheets.

The workers observed were cutting and fixing plasterboard to timber frameworks in the rear living room and underneath the staircase in the hall. 2.4 m length sheets had already been fixed vertically to the walls of the room, creating vertical joints between sheets. These sheets matched the height of the room, eliminating the need for sheets to be fixed above them.

The processes observed included measuring and scoring of one face of a sheet of plasterboard with a steel tape and a sharp knife (Figures 20, and 21). The sheet of plasterboard was then turned over and one end lifted to split the plasterboard core along the line of the score in the surface paper. The rear surface was then scored along the line of the fold in the board to complete the cut (Figure 22). The worker then placed the piece of board in position against
the timber studding and fixed it with a few nails (Figure 23). The other worker was occupied in completing the fixing of pieces of plasterboard using a mains-powered (110V) electric drill to insert screws at much closer intervals (Figures 24 and 25). He was observed to use an empty plastic tub as a hopup while carrying out this task.

The major musculoskeletal hazards associated with this task appear to be:

1. The handling of large sheets of plasterboard, both bringing them into the part of the house being worked on, and lifting them into position for fixing and holding them while fixing them. The workers felt that board trolleys were not suitable for use in the restricted spaces of houses but were useful in larger spaces in industrial developments.

2. Sustained bending while cutting sheets of plasterboard. (The individuals observed were tall, which will have increased the need to bend). A platform had been created from empty plastic tubs and wooden planks on which a number of boards had been laid. The workers said that they had brought the required number of sheets into the room when they started working in there, and the thickness of the pile had reduced. This set up may have been an *ad hoc* arrangement dependent on finding suitable items on site to create the platform; ideally the workers should carry trestles with them from site to site.

3. The need for a wide variety of reaching postures and the associated need to stand on hopups to reach higher elevations that both create a risk of falling. The postures required range from overhead nailing and screwing to nailing and screwing near floor level and in tight corners, possibly with restricted head room.

4. The need to work overhead while fixing plasterboard to ceilings. We were told that a T-shaped prop known as a ‘hangman’ was commonly used to help hold sheets of plasterboard in position on the ceiling while they were being fixed. Also, the pieces of plasterboard observed on ceilings were significantly smaller than the standard 2.4 m × 1.2 m sheets used for the walls.
Figure 20. Scoring of plasterboard

Figure 21. Scoring of plasterboard
Figure 22. Breaking of plasterboard / scoring of rear surface after scoring face surface with a sharp knife

Figure 23. Nailing of plasterboard
7.1.3. Skim coating

On the following day, skimming of dry-lined walls was observed on the second site. This was in a rear living room of a house, and by one individual. Another plasterer was carrying out skimming tasks upstairs at the time but access was impossible since, in contrast to the first site, a platform had been created across the stairwell that completely filled the opening. Also, in contrast to the first site, banister posts were in situ and had temporary boards fixed across them to prevent workers falling down the stairwells.

The plasterer used a bucket to fetch his water for mixing from a barrel outside the house (Figure 26). He then added dry plaster from a 25 kg sack (Figure 27) and agitated the mixture with a hand paddle (Figures 28 and 29). He then poured the mixture from the bucket onto a table in the room ready for use (Figure 30).

The process of skim coating a wall consists of building up a smooth surface coat of plaster of approximately 3 mm thick using two or three very thin layers. This is done over both base
coats and over plasterboard. Because of the thinness of each layer of the skim coat, the amount of plaster mixed at any one time is less and less is put onto the hawk than when applying a base coat and the float is used to spread the plaster over a much greater area in each stroke (Figure 31). As with base coats, there is the need to reach each part of the wall, causing the use of hopups to reach the top of the wall (Figure 31), and the need to stoop to reach to the base of the walls (Figure 32). The procedure observed was for the plasterer to start by working along the joints between the boards (Figure 31) and across the top of the wall and then to work along the surface of the boards to fill the gaps between the joints (Figure 32). Once the first coat had been completed and started to dry the second coat was applied in the same way. After that had dried to a certain extent the surface was given a polish with the float.

The ceiling of the room had already been plastered by the time we arrived, so this was not observed. However, we were told that the same process is used, the main difference being the need to work overhead.

The worker being observed commented that he had back problems and wore a medically prescribed corset due to an injury he had sustained when lifting a plaster bag containing waste that turned out to be heavier than he had expected.

Musculoskeletal hazards in this task appear to be as follows:

1. The need to work overhead for sustained periods while skimming ceilings. Depending on the equipment available this may be from scaffolding, from boards supported on trestles or from mobile hopups such as the ubiquitous milkcrate.

2. Hand mixing of plaster and pouring it from the mixing bucket.

3. Lifting and carrying sacks of plaster and buckets of wet plaster.

4. The need to be able to reach all parts of the ceiling and walls with the float, requiring flexibility, a wide variety of postures, and the use of hopups to reach the tops of the walls. Milkcrates do have the advantage that they can easily be repositioned using a foot but provide only a small base, so the worker will constantly have to prevent himself from overbalancing while standing on it. Also, these crates are likely to have a limited life span under such use, and dairies are unlikely to welcome losing them to the building industry.
Figure 26. Collection of water from supply outside house

Figure 27. Addition of plaster to water
Figure 28. Paddle used for hand mixing of plaster

Figure 29. Hand mixing of plaster with paddle
Figure 30. Pouring of mixed plaster onto table

Figure 31. Skim coating of top of wall
As part of a separate visit, a plasterer was observed carrying out finishing tasks on a stairwell of a large multiple storey laboratory building being built for a pharmaceutical company. Extensive scaffolding had been erected to allow safe access to all parts of the walls of the stairwell. Working from the scaffolding the plasterer polished the surface of the wall moving a wetted float in long sweeping arcs (Figures 33 and 34). This required working in awkward postures due to the restrictions imposed by the structure of the stairwell and the positioning of the scaffolding, with the need to reach over intervening scaffold poles and below the platform the individual was working from. The individual did comment that the scaffolding he was working from was the best he had ever had provided.
Figure 33. Plasterer polishing skim coat of plaster

Figure 34. Plasterer polishing skim coat of plaster
7.2. Carpenters

7.2.1. Formwork

Visits were made to two sites to look at musculoskeletal hazards associated with carpentry. The first visit was to a site where a new road was being built to replace an existing urban river bridge. Because of complex geography the road was being built as an extended flyover, crossing railway lines, the river and the local canal.

The carpenters on site were constructing formwork for concrete structures, particularly pillars to support the flyover. Conditions on-site at the time of the visit were difficult due to heavy rain, poor ground conditions and the dispersed locations of the workers. Particular activities observed included removal of formwork from the tops of pillars (Figures 35 and 36), the renewal of wooden interior facings to the large metal forms used for pillars, the construction of forms for the top of the pillar (Figures 37, 38 and 39) and the construction of forms for the foundations of the pillars (Figure 40).

It was difficult to gain an impression of the musculoskeletal hazards suffered by formworkers in this situation because of the weather and the relative lack of activity. Because of the rain the workers were wearing high visibility waterproof jackets, trousers and safety wellingtons. While providing protection from the weather, there is also the risk that these will have restricted movement and vision, thereby increasing the hazards of the wet and muddy conditions underfoot.

It would appear that tasks involved manual handling to position pieces of timber and plywood and fixing of pre-shaped pieces of formwork into position using hammers / nails and bolts. Also, tie bars holding large pieces of formwork together have large nuts which are spun into place by hand and then tightened with wrenches. A range of postures will have been required, particularly bending and stooping postures to lift items from foot level or to attach fixings at around foot level. There were also the additional hazards of working at height on scaffolding or in excavations where foundations are being constructed which may make a handling operation that would be safe in normal circumstances unsafe, resulting in an injury.

Figures 35 and 36 show a pair of carpenters removing items from the top of a flyover pillar using a rope passed over the edge of the scaffolding to lower them to the ground.

Figures 37 and 38 show the extent of scaffolding that was needed to create a safe working platform so that carpenters could work at the top of such pillars.

Figure 39 shows a carpenter handling a bulky plywood sheet within the confines of a scaffold structure. The sheet snagged on the scaffolding making it more difficult to handle. It was not clear why the boards had been stored within the scaffolding. If they were to be used at the top of the pillar then it would have been easier if they had been taken directly to the top using some kind of mechanical aid such as a rope and pulley.

Figure 40 shows a carpenter exerting force to secure a nut on a threaded bar. He is forced into an awkward posture by the height of the bar he is fixing, the narrow space he has to stand in, the sloping sides of the excavation, and the need to reach round the corner of the formwork.
Figure 35. Carpenter removing formwork from top of flyover pillar and lowering it to the ground

Figure 36. Carpenter receiving pieces of timber being lowered from top of flyover pillar
Figure 37. Flyover pillar with formwork at top

Figure 38. Top of flyover pillar prior to carpenters fitting formwork
Figure 39. Carpenter handling plywood sheets for the base of an access platform on a flyover pillar

Figure 40. Carpenters fitting forms for the base of a concrete pillar
7.2.2. *Indoor carpentry tasks*

Carpenters working indoors were observed at a large laboratory building being built for a pharmaceutical company.

When asked about musculoskeletal disorders, the carpenters spoken to commented that often it was quicker to go and fetch their own materials rather than wait for them to be brought by the labourers on the site. Generally, however, they did not respond with anecdotes of problems they had experienced, but tended to focus on more general matters of health and safety such as the way that other trades could create problems for them and the much poorer conditions they had experienced on other sites. This suggested that they did not perceive manual handling and other musculoskeletal stressors as high risks within their work.

![Carpenters hanging a door with pre-fitted hinges](image)

**Figure 41. Carpenters hanging a door with pre-fitted hinges**

A pair of carpenters was observed handling a lighter weight internal door (Figure 41). This was a door for a toilet and came with hinges attached which allowed it to be fitted by dropping it into position on the half of the hinges attached to the frame. Other carpenters were noted to be fitting internal wooden windows and door frames. The carpenters hanging the doors commented that they were stored in a container some distance from the building and that restricted access to the higher floors via stairways and the lack of availability of lifts/hoists required some doors to be carried long distances from the container to the fitting positions, including up several flights of stairs. When the lift was available they used trolleys to transport the doors.
7.3. Bricklayers

7.3.1. Parapet coping stones

At the pharmaceutical laboratory site, bricklayers were observed working on a parapet on one corner of the building at the level of the floor of the top storey of the building. It consisted of a low wall built of ordinary bricks that went a short distance along both walls from the corner with large coping stones on top. These were stored on a pallet inside the building (Figure 42a) and had to be moved up through a relatively narrow opening in the side of the building and onto a slightly raised area of scaffolding.

The bricklayers used a pallet truck to move the pallet with two stones on it (Figure 42a). To prepare the route they moved a number of metal rods (Figure 42b) and laid large sheets of chipboard to make a ramp and bridged the remaining gap with two wooden planks (Figure 43a). The sheets were poorly butted together and not fixed in position. An attempt to eliminate the bump between the planks and the sheets of plywood was made with a thinner wooden board. Considerable exertion was required to pull the truck up the ramp (Figure 43b), but the real problems occurred with attempting to manoeuvre the truck onto the planks (Figures 44 and 45). Two workers made two attempts to achieve this. The two planks were not wide enough to take both wheels under the forks of the truck so the load tilted since it was supported by the central wheel at the handle end and only one of the fork wheels (Figure 46). Also, the planks bowed as the truck was pulled across. The coping stones had holes into which a wire loop could be anchored to provide a fixing for lifting equipment. The aim was to move the stones into position using these eyes and a chain hoist suspended from a 10 ft span of scaffolding tube. Therefore, one of the workers dragged the copings across the pallet in order to bring them nearer to the hoist (Figure 47). It was then realised that the tube was not sufficiently robust to be used in this way. In addition, because the coping was some way to the side of the hoist the stone would have swung and been very difficult to control. The procedure was stopped, with the intention of strengthening the scaffolding framework to provide more rigidity and possibly using an external crane instead, when it became available.

The musculoskeletal risk factors observed in this task appeared to be:

1. Laying bricks from variable height scaffolding, and at around foot height.

2. Inadequate planning of how the coping stones should be manoeuvred into position.

3. Manual handling to overcome the limitations of the available mechanical aids.

4. Variations in levels between the inside of the building and the scaffolding, creating the need for a ramp to move the pallet truck up.

5. Inadequate material to create a safe ramp.

6. Insufficient space to manoeuvre the pallet truck in.

7. A willingness to try to achieve the task with the inadequate equipment available until stopped by the site safety manager.
Figure 42. a) Coping stones being moved on a pallet truck; b) Metal rods being moved out of the way of the pallet truck

Figure 43. a) Plank being placed to act as ramp for pallet truck; b) Pallet truck with coping stones being pulled up slope
Figure 44. Attempts to bring pallet truck over a bump in the ramp

Figure 45. Attempts to bring the pallet truck over a bump in the ramp
Figure 46. Attempts to bring the pallet truck up two planks

Figure 47. Moving coping stones across pallet to bring them closer to the block and tackle fixed to the scaffolding.
7.3.2. Bricklayers laying concrete blocks

Bricklayers were observed working on a new building being constructed in the centre of an existing hospital site. Space and access on the site were restricted due to the need for the remainder of the hospital to continue functioning and for high-level walkways to be incorporated to connect the new building to existing buildings.

Key issues raised by the site management related to:

1. The responsibility of designers in the construction process.
2. Time constraints placed on contractors to complete work.

It was stated that designers often had no thought or concept of how a job was to be carried out, and this often had a conflicting effect on health and safety: in particular the manual handling required. The short timescales often imposed on contracts mean that contractors are limited in terms of how they can carry out the work in the available time. Traditionally, the bricklayers would build the walls before the roof was installed. Once the roof was in place internal work, such as plastering or dry lining, could be carried out in dry conditions. In this case the main steel structure was put up and the roof fitted to ensure the inside was dry to allow the internal works to progress before the walls were completed. This practice results in different trades being on site at the same time which increases the difficulties of scheduling and sequencing work and if delays arise knock-on effects occur on the other trades.

Because of the construction method in use, scaffolding had been fitted all around the outside, limiting the use of mechanical aids to manoeuvre materials into place. In this case the specification was for large decorative stone window sills, columns and coping stones (Figure 48). In these circumstances they could only be manually handled into place.

Bricklayers were observed laying 140 mm paint grade 26 kg solid blocks for external walls (Figures 49 to 52) and 140 mm paint grade 19 kg hollow blocks for internal walls (Figure 53). Work at height was undertaken using scaffolding. For some awkward block positions the bricklayers used two-person lifts. The blocks were positioned in stacks on the ground near to where they were to be laid. At the time of the visit the bricklayers were positioning blocks in the waist to chest height region (Figure 52). Despite the relatively convenient positioning of the blocks there were still some awkward lifts required (Figure 51a) and the need to carry blocks short distances (Figure 51b). Because of the existence of regularly spaced vertical steel structural members there was also the need to cut blocks to fill small gaps next to these uprights (Figure 50).

Premixed mortar was being used that had been delivered. The site manager stated that they were considering mixing their own mortar on-site to decrease setting times since the premix always had retardants to slow down setting to ensure that it remained usable for as long as 72 hours. This therefore restricted the height to which walls could be built on any one day and increased the delay before further courses could be added.

A number of other manual handling operations were observed on the site, including the use of pallet trucks to move blocks around the site (Figure 54) and the use of a sledgehammer and
long wrench to position and fix structural steel work in position (Figure 55). On a higher level of the building a mechanical elevator was in use for lifting concrete blocks to the level above (Figure 56).

The musculoskeletal risk factors identified in this task were as follows:

1. Handling of 26 kg blocks, particularly to and from ground level, and possibly to head height or above

2. Handling of 19 kg blocks to head height.

3. Handling of decorative stone pieces in restricted spaces.

Figure 48. Decorative cast stone pieces for external facings
Figure 49. Handling of 140 mm concrete blocks

Figure 50. Handling of cut half of 140 mm concrete block
Figure 51. Bricklayer a) lifting and b) carrying 26 kg concrete blocks

Figure 52. Bricklayer a) positioning and b) adjusting the position of a 26 kg concrete block
Figure 53. Bricklayer lifting a hollow concrete block to approximately head height

Figure 54. Building worker pulling a pallet truck of concrete blocks

Figure 55. Building workers using a sledge hammer and long wrench to fix structural steel work in position
7.3.3. **Laying of brick / block foundations**

A visit was paid to a site where a new distribution facility for a pharmaceutical company was being constructed. The bricklayers had started work on the site in the previous few days and were engaged in building footings for the building. The steel framework of the building, the concrete first floor and the roof were already in position. Concrete foundations for the external walls were also already in position. The design called for a cavity wall of engineering bricks / 100 mm dense concrete blocks (18 kg) up to the level of a horizontal steel member approximately 600 mm above the concrete footings. The intention was that prefabricated panels would be used to infill the wall above this height.

The first course of blocks was laid flat as footers with two further courses laid vertically. The external skin of the wall consisted of approximately 10 courses of bricks.

The mortar in use was delivered premixed and stored in large plastic tubs. One of the bricklayers therefore had to shovel it from the tub into a bucket (Figure 57a) and carry it (Figure 57b) to the precise location where it was needed before emptying the bucket onto a board on the ground (Figure 58a). There was also the need to position bricks in locations convenient for laying (Figure 58b). In this case the workers made use of the metal framework to stack bricks close to hand when laying the wall underneath the framework. Workers were also observed to carry and put down boards of mortar (Figures 59 and 60). There appeared to be a difference in approach between individuals, with one carrying the board by himself (Figure 59), and another recruiting another worker to help him (Figure 60).

There were also 140 mm blocks on pallets in the yard. Some of the pallets in the yard were covered with sheeting but others were exposed and could allow ingress of water in the blocks increasing their weight.

Most issues identified were linked to the site conditions and general problems of laying lower courses of blocks / bricks. The steel structure of the building constrained postures because it
got in the way (Figures 61 and 62). The very narrow trenches seen in several positions made it tricky to lay the blocks (Figures 71 to 73) and the bricklayers were conscious of the risk of dislodging blocks with their feet, or the trench walls collapsing, or leaning onto the wall while the mortar was still wet. It was stated that the trench was made as narrow as possible to cut excavation costs and the need to dispose of more soil.

As can be seen from Figures 64 to 73, there are a wide variety of manual handling issues to do with handling bricks and blocks in this situation. Most of them stem from the need to work at or near foot level forcing the workers to stoop or crouch for extended periods. Also, there is inevitably much asymmetrical handling involved in transferring a brick or block from a pile to its final position in the wall (Figures 66 and 67). Even relatively light tasks, such as spreading a bed of mortar (Figure 61a), requires an asymmetrical transfer of mortar from the board (Figure 60b), usually with a certain amount of working of the mortar with the trowel on the board to ensure its usability. There is also the need to cut bricks or blocks to fill small gaps (Figure 63). The laying of blocks, because of their weight and size, produced much more awkward asymmetrical postures and the need, especially with the bottom course, for the worker to reach in front of himself to position the block (Figure 65). Because the blocks had already been positioned close to the wall the amount of carrying of blocks was relatively limited. The issue of restricted footroom in the base of a trench was particularly clear on one part of the site where the bricklayer was forced to stand with one foot in the trench and to kneel with the other on the edge of the trench while positioning blocks at the bottom of the trench (Figures 71 to 73). The way that the bricklayers were working from inside the building meant that they had to lay the external skin of bricks before they could lay the internal blocks, thereby restricting their options even more.

An issue that the bricklayers raised as a common problem (though not relevant to this site) was the problems that can be created by scaffolding. One commented that the scaffolding is there to help them do their job but is often not to their requirements. In particular, scaffolding is not always positioned at the correct distance from the wall. A 75 mm gap is required between the boards and the wall to enable a spirit level to fit into the gap to check the trueness of the wall. If the gap is larger the bricklayer has to do more reaching, particularly on corners. On the other hand if the gap is too small, it is possible for the scaffolding to actually push the wall out of true while the mortar is still wet. Also, scaffold lifts don’t always suit course heights meaning that low courses can be below the level of the scaffold board forcing bricklayers to work below the level of their feet.

On several occasions it was commented that WMSDs and back problems often seem to occur first thing in the morning on colder days. Some prefer to do lighter duties first as a warm-up.

Musculoskeletal hazards identified on this site were:

1. Manual handling in squatting and stooping postures
2. Handling of blocks weighing 18 kg near ground level and with asymmetric postures.
3. Working on muddy and uneven ground
4. Working in trenches of restricted width, especially when laying the bottom layer of blocks.

5. Manual handling of mortar, both shoveling from deep tubs and carrying of buckets and boards of mortar.


7. Postural stress due to structural steelwork creating obstructions.

**Figure 57.** a) Shovelling mortar from a plastic tub; b) carrying mortar

**Figure 58.** a) Pouring mortar onto board on ground; b) Carrying bricks
Figure 59. Carrying and putting down a mortar board

Figure 60. a) Carrying a mortar board; b) Picking up mortar with a trowel
Figure 61. a) Spreading a bed of mortar onto a layer of bricks; b) Laying a brick

Figure 62. Tapping a brick into position
Figure 63. Cutting a) a brick and b) a concrete block

Figure 64. Laying bricks
Figure 65. Laying concrete blocks

Figure 66. Handling concrete blocks
Figure 69. Laying a concrete block

Figure 70. Positioning a concrete block

Figure 71. Laying concrete blocks in a trench with restricted foot room
Figure 72. Laying concrete blocks in a trench with restricted foot room

Figure 73. Laying concrete blocks in a trench with restricted foot room
8. POSSIBLE FUTURE DIRECTIONS FOR HSE RESEARCH ON WMSDS IN CONSTRUCTION WORKERS

8.1. Bricklayers

8.1.1. Scope for taking action

There is scope for action to ensure that block sizes and weights are chosen with due regard to the problems of manually handling them into position. In particular, designers and architects should specify the minimum weight block necessary for the intended use.

8.1.2. Type of action most likely to be effective

1. Encouraging the industry to make more use of the solutions that already exist to the problems of manual handling.

2. Encouraging the industry to consider the manual handling problems created by the method of construction specified, particularly the effect of the weight of the block.

3. Encouraging the industry to continue the development of new types of block that are easier to handle, e.g., smaller, lighter, less dense, hollow, or with handholds.

4. Encouraging the industry to provide raised platforms for supplies of bricks / blocks and mortar. This will reduce the need for stooping to lift materials before placing them in position in the wall.

5. Ensuring that scaffolding is constructed in a manner which helps the bricklayers perform their job.

6. Encouraging the elimination of laying of brick or block foundations in very narrow trenches.

8.1.3. Recommendations for further work

Possible items for future research that HSE might consider relating to musculoskeletal disorders in bricklayers are:

1. Examination of the feasibility of workers laying foundations working in pairs so that one hands the bricks / blocks down to the other to eliminate awkward reaching from the trench.

8.2. Carpenters

8.2.1. Scope for taking action

Because of the large numbers of carpenters and the wide range of tasks they perform, there will be wide scope for action to reduce the risks of musculoskeletal disorder among them.
8.2.2. **Type of action most likely to be effective**

1. Encouraging the industry to make more use of the solutions that already exist to the problems of manual handling.

2. Ensuring that suitable mechanical handling aids are available.

8.2.3. **Recommendations for further work**

Possible items for future research that HSE might consider relating to musculoskeletal disorders in carpenters are:

1. More detailed study of carpenters, subdividing them into specialties, and using task analysis to examine the musculoskeletal loading factors in each speciality.

2. Examination of the current generation of handheld power tools to identify poor design features.

8.3. **Plasterers**

8.3.1. **Scope for taking action**

It is surprising that there is so little information available on musculoskeletal disorders in plasterers and floor screeners. While there is some recent information available on drylining, this all originates in North America, where drylining is seen as a subspeciality of carpenters. The site visits showed that both drylining and wet plastering are heavy manual tasks that require the ability to handle bulky and heavy materials, and the ability to work in a wide variety of postures due to the amount of reaching required. The move, with HSE’s encouragement, by the industry from 50 kg bags to 25 kg bags of raw materials will have already decreased the risks of manual handling of heavy loads.

8.3.2. **Type of action most likely to be effective**

1. Encouraging the industry to make more use of the solutions that already exist to the problems of manual handling.

2. Ensuring that all levels of the industry plan work to eliminate unnecessary manual handling.

3. Ensuring that suitable access equipment and manual handling aids are provided for the workers on sites.

4. Ensuring that adequate and safe methods of working on ceilings and upper parts of walls are provided. We did not hear of stilts being used in this country, unlike North America, but such a method seems inherently unsafe.

5. Encouraging the industry to use narrower sheets of plasterboard, to reduce the weight and increase the ease of handling.
8.3.3. **Recommendations for further work**

Possible items for future research that HSE might consider relating to musculoskeletal disorders in plasterers are:

1. Work on floor screeders to identify the levels of musculoskeletal disorders they are suffering from and the specific risks they encounter in the tasks they undertake.

2. More detailed work on wet plastering, both base coat and skimming.

3. Comparison of drylining and two-coat wet plastering to determine whether one method is more preferable in terms of reduced manual handling and risks of musculoskeletal disorders.

4. Work on the risks of working overhead such as drylining and skimming ceilings.
9. REFERENCES


Reference List


