Broad Lane, Sheffield, S3 7HQ
Telephone: 0114 289 2000
Facsimile: 0114 289 2500

HEALTH & SAFETY LABORATORY

# Manual handling in the brick production industry: Results of a study of the ergonomics of brick packing

**HSL/2000/20**

**Project Leader: Andrew DJ Pinder**

**Andrew DJ Pinder, PhD, MSc, MErgS, Eur Erg**

**Human Factors Group**

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## Summary

### Objectives

1. To examine the levels of risk, and the relative risks, of musculoskeletal disorders in the back and upper limbs from the different methods currently in use for manual sorting and packing of bricks in the brick production industry.

2. To compare the ergonomic risks of manual brick sorting / packing using a semi-mechanised system of jigs on a 'monorail' and completely manual hand packing.

3. To compare the ergonomic risks of handling four or five bricks at a time to handling two bricks at a time.

### Main Findings

1. The levels of musculoskeletal trouble found in the wrists / hands and the lower back of brick packers were far greater than the levels previously reported by bricklayers and the rest of working population.

2. There were significantly more reports of musculoskeletal trouble in hand packing than in monorail packing plants. 87% of hand packers and 72% of monorail packers reported lower back problems in the previous year ($\chi^2 = 4.33$, $P < 0.05$). 48% of hand packers and 26% of monorail packers reported problems in the wrists / hands in the previous week ($\chi^2 = 7.22$, $P < 0.01$). 32% of hand packers and 15% of monorail packers reported problems in the upper back in the previous week ($\chi^2 = 5.29$, $P < 0.05$).

3. The practice of 'Job and Finish', where workers can leave when they have completed their daily target was found to occur in hand packing plants. Two monorails visited had ceased using the system. This practice was associated with a greater annual prevalence of low back pain and a greater annual disability due to problems in the wrists / hands than other hand packing.

4. Very few plants had succeeded in implementing a 'maximum brick limit' of two bricks. There is a preference among packers to handle larger numbers of bricks per lift and perform fewer lifts rather than handling only a few bricks in each lift. There were some differences in prevalence of musculoskeletal trouble for different maximum brick limits but the associations were fairly small and there was no clear pattern in the findings.

5. Brick packing is a fairly strenuous task physiologically. Hand packing was found to be more strenuous than monorail packing with a mean working heart rate higher by 8.8 beats per minute ($t = 2.45$, $P < 0.05$). Physiologically, hand packing was ‘heavy work’ and monorail packing was ‘moderate work’. Both methods had mean Ratings of Perceived Exertion in the ‘Very Hard’ region but hand packing was rated as more strenuous ($t = 2.82$, $P < 0.01$).

6. Mean working heart rate in plants where job and finish systems were used (‘heavy work’) were 14.5 beats per minute higher ($t = 2.79$, $P = 0.01$) than in other hand packing plants (‘moderate work’).

7. It appears that shift lengths exceeding nine hours do not adversely affect the physiological load. Overall, the workers measured were not suffering excessive levels of fatigue as a result of their work. The present system where generous rest breaks are provided is almost certainly what keeps the task from being physiologically excessive.

8. Insufficient data were collected to show a difference in heart rate due to a maximum brick limit being enforced. The data collected merely suggest that there is no difference.

9. The ways in which workers handle bricks and therefore the postures they adopt are very largely determined by the layout of the workstation and the layouts of both the kiln packs and the despatch packs.

10. In terms of the OWAS system for classifying gross postures, hand packing is worse than monorail packing as it generally involves more bending and stooping due to the lower heights that the despatch packs are positioned at.

11. Only small percentages of time were spent in postures linked to the worst two OWAS Action Categories. On monorails, approximately two-thirds of observed postures were classified as not requiring remedial action. However, for the hand packing sites over 50% of the postures were classified as requiring remedial action.

12. Development of preemployment tests to predict job performance and hence risk of injury is a major undertaking with definite limitations. It would be unreasonable to expect a relatively small industry such as the brick manufacturing industry to do this.

## Main Recommendations

1. The long-term trend within the industry towards the mechanisation of both packing and setting should be strongly encouraged.

2. Due to the nature of some clays and kilns and bricks, manual sorting and packing will need to continue in some circumstances, particularly where waste rates are high or where production volumes are low. In these circumstances, companies must take a proactive approach to management of the risks to musculoskeletal health.

3. Firms should carry out detailed manual handling risk assessments and identify possible solutions to the identified problems. Once changes to workplaces and working practices have been made the risk assessments should be revised to reflect the changes made and they should be reviewed at regular intervals to monitor the effectiveness of any changes made and the ongoing occurrence of musculoskeletal problems.

4. Workstations and the kiln and despatch packs should be redesigned to decrease the amount of reaching, bending and twisting required in packing. Kiln packs should be designed to dissuade packers from lifting very large numbers of bricks in a single lift.

5. Appropriate and specific training should be given to packers in manual handling techniques suitable for the particular plant.

6. Where manual packing is occasionally required in mechanised systems, steps should be taken to limit exposure to individual workers.

7. The working day and working week should be organised to spread the handling of loads to reduce the risk of cumulative injury.

8. Practices such as job and finish, which encourage workers to work excessively fast in order to leave early, should be phased out and workers should be encouraged to take regular breaks throughout the day.

9. Teamwork and rotation should be actively encouraged on monorails.

10. Preemployment / placement medical screening of new employees or existing employees being transferred to packing duties should be carried out and health surveillance systems should be created to monitor the incidence and prevalence of musculoskeletal problems.

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# 1. INTRODUCTION

## 1.1. User Guide: How to find your way round this report

This report uses scientific and statistical terminology which may be unfamiliar to many readers. The report is structured in a way that is conventional for scientific reports and makes extensive use of tables and graphs to present information in a way that is more understandable than plain text. The different sections of the report and their purposes are set out in Table 1:

**Table 1: Structure of this report**

| Report part | Purpose |
|---|---|
| INTRODUCTION | This discusses the background to the project reported. |
| METHODS | This describes the scientific methods used in the project and the measurements obtained |
| RESULTS | This discusses the measurements made and the information gathered and highlights specific findings |
| DISCUSSION | This draws conclusions from the information gathered |
| RECOMMENDATIONS | This recommends ways in which the findings of the study can be used to make changes in the brick manufacturing industry |
| BIBLIOGRAPHY | This lists the articles in the scientific literature and other relevant publications referred to in the report |
| APPENDIX 1: STATISTICAL TERMINOLOGY | This offers brief definitions and explanations of the statistical terminology used in the report |
| APPENDIX 2: OTHER DOCUMENTATION | This contains information sheets, consent forms, and the questionnaire used. |

Full details of the contents of the report are set out in the Table of Contents, along with lists of the Tables and Figures that appear in the report.

It is suggested that a first reading of the report should concentrate on the Introduction and Discussion and Recommendations. Whenever statistical terminology is used reference should be made to Appendix 1 for definition and explanation. A second more detailed reading of the report should include the Methods and Results sections so that the basis of the Discussion and Recommendations can be seen. The main methods used are listed in Section 2.2 and then explained in detail. Each subsection of the Results has a list of bullet points at the end showing the important finding discussed in that section.

## 1.2. The identified problem

This project arose because of concerns about the level of risks and musculoskeletal injuries in the brick manufacturing industry. The brick manufacturing industry acknowledges that manual sorting and packing of bricks is a high risk activity for musculoskeletal disorders in the back and upper limbs. Different methods of packing and different quality control / inspection policies affect the methods of manual handling used in the industry. Due to uncertainties about the levels of risk, the relative risks of the different methods currently in use, and the costs of introducing fully mechanised systems, the HSE Ceramics and Heavy Clay National

Interest Group realised that an industry wide approach was required to ensure equitable treatment of different firms and plants. Therefore, after consultation with the British Ceramics Confederation, the Ergonomics Section of the Health and Safety Laboratory, an HSE owned laboratory, was asked to undertake a field investigation to examine these issues.

## 1.3. Technical background

### *1.3.1. Brick production*

Bricks are fired in kilns at temperatures of about 1200°C in stacks with spaces for hot gases to circulate. After firing they are allowed to cool and then transferred to tightly packed despatch packs. Usually, to ensure blending of colour variations, bricks from several kiln packs are mixed to make up each despatch pack. As they are packed bricks are inspected for defects such as excessive colour variations (‘seconds’ or ‘commons’) and cracks (‘rejects’ or ‘waste’). The terminology used for the different grades of brick varies between plants. The amount of variability accepted, especially in terms of colour, in ‘best’ bricks depends upon the market segment the bricks are sold into. Some bricks are deliberately burnt to produce a wide range of colour variations within the kiln pack and hence within the despatch pack. Depending on the type of brick, the nature of the clay and the design of the kiln, normal defect rates range from over 10% to under 1%. Where problems in firing occur reject rates can be very high.

Some plants use fully automated packing systems and have eliminated manual packing except for removal of seconds and rejects or in the event of mechanical breakdown. (The trend over recent years in the industry has been towards mechanisation throughout the production process, including packing). Other plants use mechanised jigs (‘monorails’) in which the despatch packs are built up. These jigs are indexed between packing workstations at fixed intervals. Each worker is expected to place a set numbers of bricks into each jig before it moves on. In other plants packing is carried out ‘floor to floor’, from a fixed kiln pack to a fixed despatch pack, usually in a fixed jig. In these systems workers are given a set number of bricks to pack and allowed to work at their own pace. In a small number of plants bricks are transferred mechanically from kiln packs onto a conveyor and then packed manually into jigs.

Standard brick dimensions are 102.5 mm deep × 65 mm high × 215 mm long. Smaller numbers of 73 mm high bricks are produced. A variety of methods of manufacture are used. ‘Hand made’ bricks involve a worker manually throwing or forcing clay into a mould and then removing the shaped brick. (Hand making is not dealt with by this report). ‘Wire cut’ bricks are extruded and cut to the correct height. Wire cut bricks usually are extruded with three or more holes forming up to 25% of the volume. Pressed bricks are made by a machine forcing clay into a mould and will often have a frog pressed into the brick. The ‘green’ bricks produced by all of these methods are made oversize because shrinkage occurs during drying and firing. They also lose weight during firing. ‘Body fuel’ may be added to the clay to change the characteristics of the fired brick, or self-burning clays may be used. As the appearance of the final product affects its marketability, consumer preference and fashions are important considerations. Decorative finishes may be added to the facing edges of the brick during pressing or extrusion. The final appearance of the faces will also depend on the stacking pattern used, the type of kiln and the control of the burning process.

Fired bricks typically weigh in the region of 2.0 - 2.5 kg each, though some types weigh as little as 1.8 kg, and engineering bricks can exceed 3.0 kg. A wide variety of inspection policies exist in the industry. The overall intention is to keep the defect rate below what the end user considers acceptable. (Damage may also occur to bricks in transit). Inspection policies may demand that each packer handles no more than two bricks at once (one per hand) or may permit handling five or more bricks at once (usually held between the hands). Limits may also be imposed in an attempt to control the risks due to manual handling. These limits are referred to as 'Maximum Brick Limits' (MBL). Loads handled at any instant can therefore be up to 12.5 - 13 kg, or occasionally more. Typical total loads handled are between 20 - 30 tonnes per person per day. Kiln packs are typically up to 1.5 m high, depending upon the design of the kiln.

### *1.3.2. Size of the manual handling injury problem in the brick production industry*

In 1998 the BCC estimated that approximately 650 workers were employed by member firms in hand sorting / packing. A BCC survey (BCC, 1998) of brick manufacturing plants recorded that the number of workers employed in hand packing in the plants surveyed ranged from four to 57. The survey also showed that 13 sites using monorails had reported under RIDDOR 95 21 three-day accidents during 1996 and 1997. Five sites had no accidents during this time, and four had one each. Two monorails had two accidents, one had five, and one had eight. The plant that reported eight accidents had only eighteen workers involved in packing. At 17 sites employing hand packing there were 16 accidents reported during the same period. Eight sites had no accidents, four had one, three had two, and two had three. Of the firms reporting three accidents one had twenty packers, and the other had only four packers.

It can be shown from figures obtained by the BCC survey that the production rates (bricks per worker per shift), weighted by numbers of workers on each site, were virtually identical for monorails and hand-packing at 14178 and 14167 respectively. It can also be shown that the reportable accident rates experienced by firms ranged from 0 to 0.222 accidents per worker per year (weighted mean 0.0536) on monorails and from 0 to 0.375 accidents per worker per year (weighted mean 0.0316) on hand packing. This difference is not statistically significant ($\chi^2 = 0.006$, $P > 0.05$) (see Appendix 1 for statistical terminology). For both systems the mean rate is near the lower end of the distribution. The work time lost ranged from 0 to 1.625 days per worker per year (weighted mean 0.250) on monorails and from 0 to 5.25 days per worker per year (weighted mean 0.356) in hand packing. Again, the difference was not significantly different ($\chi^2 = 0.026$, $P > 0.05$), and again, the mean was near the lower end of the distribution, which is therefore skewed by a few high values. These findings suggest that if an unfavourable set of circumstances occurs, severe problems can arise in either system and a temporary high injury rate in one plant could make one type of packing temporarily appear much worse than the other.

The BCC (1998) described two questions as unresolved:

1. The relative risks of hand packing and packing on monorails;

2. The relative risks of handling 5 bricks at a time and of handling 2 bricks at a time and therefore lifting 2.5 times as often.

### 1.3.3. Other available information on the brick industry

A very old study of health problems in brickworks (Keatinge and Potter, 1949) reported on the results of medical examination of 100 workers in four plants. No mention is made of any musculoskeletal problems though nine are reported as having or having had hernias or inguinal weakness. Comment is made on "the possibility of ill health due to the arduous nature of the work". The "absence of all forms of mechanized help in the operation of the kilns" is described as one of the most striking features of these works. It is also noted that green bricks were transported to the kilns by trolley and then stacked by hand at a rate of 1000 per hour. Men engaged on drawing fired bricks from the kilns stacked bricks in fifties on a wheelbarrow and then wheeled it to a waiting lorry where they were stacked onto the lorry, averaging 15,000 bricks, or 300 journeys, per day.

Two small scale studies of upper-limb disorders in brick manufacturing have been carried out. The first (Ferreira and Tracy, 1991) compared work practices in two plants with monorails which had different injury rates. They suggested that differences in work organisation and methods of handling could be influencing the injury rates. They characterised the plant with more injuries as having handling techniques and work organisation which lacked variety. The other plant was characterised by versatility, particularly since a wide variety of handling techniques were used.

The second study (Basra and Crawford, 1995) found that subjects were having to adopt poor hand-arm postures, and that nearly all subjects were spending over 50% of their task time in detrimental postures.

A laboratory study (Webb and Handyside, 1982) showed that a small change in brick dimensions resulted in an increase in the perceived workload and heart rates of men loading and unloading pallets of bricks by hand. This was because the change in dimension meant that the grip had to be changed from holding two bricks in each hand to holding four bricks between both hands. This resulted in subjects having to stoop more.

### 1.3.4. Physical demands in other heavy industries

Astrand (1967) measured heart rates of building workers carrying out their normal work. She found a mean heart rate for 10 bricklayers of 97.9 bpm (SD 9.5 bpm).

The American Industrial Hygiene Association published in 1971 an 'Ergonomics Guide to Assessment of Metabolic and Cardiac Costs of Physical Work'. This concluded that, "The reported evidence suggests that few men exhibit an average rate (including rest periods) higher than 110-120 beats per minute during day-to-day employment. A more usual average rate for physically active workers is 90 - 100 beats per minute."

Astrand *et al.* (1973) measured heart rates in coastal fishermen over an entire working day. They found that heart rate was below 110 bpm for 90% of the time and that rates between 120 and 140 bpm were maintained for 10% of the time. Mean heart rate was 108 (SD 12) bpm.

Rodahl *et al.* (1974) extended this study. The heart rate exceeded 50% of the fishermen's heart rate reserve for, depending on the type of fishing, between 9 and 23% of the time spent on board the boat. They noted that long stretches of physical rest are inherent in coastal fishing, and that many of the activities on board are intermittent in character, so that high levels of energy expenditure are immediately compensated by recovery pauses.

Louhevaara *et al.* (1988) measured heart rates of postal workers sorting parcels at their 'habitual rate (of 8.6 ± 2.4 parcels per minute) as 105 ± 22 bpm. Palenciano *et al.* (1996) found an average heart rate over a shift (including rest breaks) of 97.7 bpm (SD 9.2 bpm) in miners extracting coal with pneumatic drills and a resting heart rate of 59.1 (SD 6.3) beats per minute. They noted that there were considerable inter-individual differences. In an earlier study of miners in a poorly mechanised mine they had found an overall heart rate of 106.5 (SD 18.2) bpm (Montoliu *et al.*, 1995).

A risk assessment carried out by a firm using a monorail noted that even experienced packers experienced wrist problems on returning to work after extended layoffs or even holidays. This was attributed to workers packing at the rate they had become accustomed to before the extended break and therefore overstressing their bodies which had become 'untuned'.

### 1.4. Aims / objectives of the project:

In the light of the background information discussed above, the following aims were defined for the project:

1. To compare the ergonomic risks of manual brick sorting / packing using 'monorails' and hand packing from the floor.

2. To compare the ergonomic risks of handling 4/5 bricks at a time to handling two bricks (an MBL of 4/5 versus an MBL of 2).

The project was also intended to help to address the following issues:

1. Detailed risk assessments for each site visited

2. The occurrence of low back problems and upper-limb disorders in the sites visited

3. Best practices observed

4. Priorities for action by HSE and the industry

5. Possible improvements to the industry specific guidance on manual handling

Issues 1 and 5 are not dealt with in this report but will be dealt with elsewhere.

# 2. METHODS

## 2.1. Experimental design and scientific protocol

### *2.1.1. Initial plan*

At the start of the project the intention was to combine the study of the two factors identified by the BCC (1998) into a 'factorial design'. The intention was to study six sites using monorails and six sites using hand packing, three of each handling up to 4/5 bricks at one time, and three of each handling two bricks at a time, as shown in Table 2. This would allow both questions to be asked at the same time and would require fewer measurements than separate studies of both issues.

**Table 2: Planned factorial experimental design**

| MBL | Hand packing | Monorail packing | Totals |
|---|---|---|---|
| **2 bricks** | 3 plants | 3 plants | **6 plants** |
| **4/5 bricks** | 3 plants | 3 plants | **6 plants** |
| **Total** | **6 plants** | **6 plants** | **12 plants** |

### *2.1.2. Revised plan*

After the project started it was discovered that maximum brick limits (MBL) of 2 bricks were in use in a few hand packing sites, but no monorails had such a limit. Therefore it was decided to still collect data at six monorails and six hand packing sites. This would allow the comparison of monorails and hand packing to be made. It was decided to examine the issue of brick limits within hand packing only, by collecting measurements at three plants with an MBL of 2 and three with an MBL of 4/5 or no limit.

The net result of this change was to substitute three monorails with MBLs of 4/5 for the non-existent monorails with an MBL of 2. Even this amended experimental design proved impossible to implement. It was found that very few hand-packing plants have MBLs of 2, and only two could be identified. A plant was identified which had an MBL of 3, and this was therefore visited with the intention of grouping it with the plants with MBLs of 2. Once at this site it was found that the MBL was ignored by the packers who would often handle as many as 7 or 8 bricks at once. The MBLs in force at the plants visited are listed in Table 9.

## 2.2. Measurement techniques

Three measurement techniques were identified as suitable for the project:

1. Assessment of the prevalence of musculoskeletal trouble (ache, pain, discomfort or numbness) using the HSE version of the Nordic Musculoskeletal Questionnaire (NMQ). This would determine how likely brick packers are to suffer from musculoskeletal problems.

2. Assessment of the energy requirements of packing by measurement of heart rates over the duration of the working day. This would determine how hard the packers have to work.

3. Assessment of postures adopted by packers using video recording and the OWAS posture coding technique. This would determine whether the postures the packers adopt to perform the job are likely to be detrimental.

Brief descriptions of these techniques are given in Sections 2.2.1 to 2.2.3, and more detail is given in Sections 2.9, 2.11 and 2.12.

### *2.2.1. The Nordic Musculoskeletal Questionnaire*

The NMQ is a standard questionnaire (see Appendix 2) which has been adapted by HSE (Dickinson *et al.*, 1992) and used by HSE to survey the prevalence of musculoskeletal 'trouble' across a number of work forces, including supermarket workers (Mackay *et al.*, 1998) and lock assemblers (Williams and Dickinson, 1997). Musculoskeletal trouble is defined by the questionnaire as 'ache, pain, discomfort or numbness'.

Using an existing questionnaire had the advantages of allowing comparison with previous data sets. Creating a new questionnaire, or even modifying the NMQ, would have increased the difficulty of using the questionnaire approach because the new questionnaire would have had to be validated and piloted.

Respondents are asked to complete three sections. The first deals with 'Personal details' and asks for date of birth, whether the respondent is male or female, the date of completion, weight and height and handedness. The second section is 'About your job' and asks for job title, the time which the respondent has been doing the present type of work at the current site; whether similar work had been done elsewhere and the total time this had been for. It also asks for the average number of hours worked per week, including overtime, but excluding main meal breaks.

The third section is about 'Musculoskeletal disorders' and is linked to a diagram of the body which identifies nine body regions. Three questions are asked about each of these regions:

1. **'Annual prevalence'** of musculoskeletal 'trouble' is measured by questions which ask whether 'during the last 12 months' the respondent has experienced 'trouble (such as ache, pain, discomfort, numbness)' in each of the nine body regions.

2. **'Weekly prevalence'** of musculoskeletal 'trouble' is measured by questions which ask, for each body region, whether the respondent has had trouble 'during the last 7 days'.

3. **'Annual disability'** caused by musculoskeletal 'trouble' is measured by questions which ask whether such 'trouble' has, during the previous 12 months, prevented the respondent from 'carrying out normal activities (e.g., job, housework, hobbies)'.

Subjects were also asked to give ratings of perceived exertion (Borg, 1998). This measure has been used in previous HSL laboratory studies of manual handling tasks (e.g., Pinder *et al.*, 1998). The RPE scale was photocopied onto the blank back page of the pre-printed copies of the NMQ and is also reproduced in Appendix 2.

### *2.2.2. Heart rate measurement*

The assessment of the energy requirements of packing was done by measuring heart rates over the duration of a normal shift for up to four workers at each plant. This was done using Polar Heart Rate Monitors which are widely used wireless transmitters and receivers. This allowed comparison of packing with accepted levels of strenuousness of work tasks.

### *2.2.3. Posture analysis*

To allow the assessment of the postures adopted by the packers, and hence the influence of the different packing methods on posture, video recordings were made over the course of the shift of the workers whose heart rates were being measured. This approach had the advantages of being non-invasive and unobtrusive and unlikely to affect greatly the behaviour of the workers and allowed the normal variations of posture over the day to be assessed. Postures were assessed using the computerised OWAS (Ovako Working posture Analysis System) software (Karhu *et al.*, 1977, 1981; Vayrynen and Kononen, 1991; Kivi and Mattila, 1991; Mattila *et al.*, 1993; Hignett, 1996). The OWAS method is a means of relating time-sampled postures to 'Action Categories' based on the perceived harmfulness of the postures, making recommendations for the urgency of remedial action to prevent the need for the postures to be adopted by individuals carrying out their work (Karhu *et al.*, 1977, 1981).

A number of devices are available which allow direct measurement of body positions or joint angles. These include motion analysis systems such as the MacReflex (Qualisys AB, Sweden). These systems usually require the use of either passive reflective markers or active infrared markers which are attached to the skin at the points of interest. They also require the use of multiple detection devices, usually surrounding the workplace and may require careful control of lighting conditions. They are most easily used in laboratory conditions and would be unsuitable for use, especially sustained use, in brick packing plants where lines of sight are often obscured by machinery and packs of bricks, lighting levels and reflections could not be controlled and markers would have to be attached to individual's clothing and would be in danger of being damaged or dislodged by contact with bricks or machinery.

Other systems allow the measurement of body angles. These include systems such as bi-axial electrogoniometers and torsiometers (Biometrics Ltd, Gwent, UK) which can be attached to the body over the joint of interest. While these have been used in industrial applications (Boocock *et al*., 1994), they are not capable of sampling for very extended periods, have to be attached to the skin under clothing, and can become detached or damaged. Multiple devices would be required to look at multiple joints.

The 'Lumbar Motion Monitor' (LMM) is a system which allows the computerised measurement of spinal postures in three dimensions. It is worn as an exoskeleton attached to the pelvis and upper back. It has been used to predict the likelihood that a worker is a member of a group of workers at high risk of developing back problems (Marras *et al*., 1995). The difference is subtle, but it does not predict the likelihood that an individual will get back pain. It would be able to identify from the motion patterns used that someone was engaged in brick packing and therefore likely to suffer from back pain, but it would not be able to distinguish an individual packer likely to get back pain from one unlikely to get back pain. This system was unsuitable on a number of grounds, particularly high cost, lack of availability in Europe, the intrusive nature of the exoskeleton and harnesses, and the need for a wired link to a computer. A similar system known as the BackTracker has similar disadvantages.

## 2.3. Power calculations

### *2.3.1. Prevalence of musculoskeletal trouble measured with the NMQ*

The initially proposed experimental design was a 2 × 2 analysis (Table 3) where frequencies of occurrence of reports of discomfort would be compared using the $\chi^2$ test (see Appendix 1 for explanations of statistical tests). Likely subject numbers were estimated as a mean of 15 at each site since the BCC (1998) found that 196 workers were employed on 13 monorails (mean of 15.0) and 253 workers were employed at 17 hand packing sites (mean of 14.9).

**Table 3: Proposed subject numbers**

| MBL | Measure | Monorails | Hand packing | Total no of subjects |
|---|---|---|---|---|
| **2 bricks** | **NMQ** | 15 subjects × 3 sites | 15 subjects × 3 sites | 90 |
| | **Heart rate** | 4 subjects × 3 sites | 4 subjects × 3 sites | 24 |
| **4/5 bricks** | **NMQ** | 15 subjects × 3 sites | 15 subjects × 3 sites | 90 |
| | **Heart rate** | 4 subjects × 3 sites | 4 subjects × 3 sites | 24 |
| **Total no of subjects** | | 90 (NMQ); 24 (HR) | 90 (NMQ); 24 (HR) | 180 (NMQ); 48 (HR) |

Required sample sizes were calculated, using GPOWER.EXE, which implements the power formulae of Cohen (1988). For a $\chi^2$ test, conventional effect sizes are small: w = 0.1; medium: w = 0.3; and large: w = 0.5. For a 2 × 2 test, a significance level of 0.05 and a power of 0.95 this gave required total sample sizes of 1300, 145 and 52 respectively. Also, an effect size was estimated from the weekly prevalence data of Williams and Dickinson (1997) who showed significant differences ($p < 0.001$) between six sites for musculoskeletal trouble in the neck. Their data were used to calculate expected frequencies as percentages of the total number of cases, which were entered into the 'Calc Effectsize' option of GPower. This gave an effect size, w, of 0.3561 and a required total sample size of 103. It is clear that the projected sample size of 180 would give sufficient power for both a 'medium' effect and the effect size estimated from the data of Williams and Dickinson (1997).

### *2.3.2. Heart rate measurement*

Power calculations for heart rate measurements were done for an *a priori* analysis of a 2 × 2 factorial analysis of variance as set out in Table 3, with three sites per cell and four subjects per site. Each of the main effects and the interaction between them has a single degree of freedom and therefore each test has the same power. The conventional effect sizes for Anova of: f = 0.10 = small; f = 0.25 = medium; and f = 0.40 = large were used. For a significance level of 0.05 and a power of 0.95 these required total sample sizes of 1302, 210 and 84 respectively. For a power of 0.8 these reduced to 787, 128 and 52 respectively.

An effect size of 1.0 was also used. This was based upon a laboratory study by Webb and Handyside (1982) who compared heart rate responses of 10 students to lifting four bricks held between two hands (4/2) and lifting two bricks in each hand (2/1). Heart rates were approximately 20 beats per minute higher in the 4/2 condition than in the 2/1 condition ($P < 0.001$). Standard deviations were estimated from their graph as about 15 beats per minute, giving an effect size of 20/15, i.e. 1.3. This was rounded down to 1.0, thus allowing for the inexperience of their subjects which is likely to have inflated heart rate responses. For a significance level of 0.05 and a power of 0.95 this required a total sample of 16.

These analyses showed the intended sample size of 48 to be almost sufficient to give a power of 0.8 for a 'large' effect. Even a conservative estimate of effect size based upon the single known relevant previous study showed that the proposed sample size had ample power.

## 2.4. Ethical approval / ministerial approval

As the study involved human subjects and was not carried out as part of an HSE inspection, approval by the HSE Research Ethics Committee (REC) was necessary. After initial consideration of the proposal the REC asked for clarification of a number of issues. Once this had been done approval was given.

Also, because the study involved asking more than 25 individuals to complete a questionnaire, it fell under the scope of the Survey Control procedures which require government departments to obtain ministerial approval before undertaking statistical surveys in industry. The small size of the survey meant that the survey was classed as a minor survey and approval could be granted under the accelerated survey control procedure. This involved submitting the proposal to the HSE Survey Control Liaison Officer rather than to the Office for National Statistics. Once this approval, and internal HSL approval, had been gained the proposal was submitted to the HSE Chief Scientist, then to the Chairman of the Health and Safety Commission before finally being submitted to the Minister of State in the Department of Environment Transport and the Regions who had responsibility for HSE. Once this approval had been gained it was possible to start visits to companies.

## 2.5. Site visits / discussion with company representatives and workers

The majority of the sites visited were from a list of plants identified as suitable by the Ceramics NIG. As the project progressed other sites were identified as suitable from discussion with industry representatives. Contact was made with company representatives to discuss suitability and potential dates for visits. These contacts were with company safety officers, and/or individual plant managers, or deputy managers. Once it was confirmed that a plant was suitable and that the company were happy to cooperate, a preliminary visit was arranged.

This visit was used to explain the project in detail to the local management and union representatives, where available, to ensure their active co-operation. It also gave an opportunity to gather background information on matters such as the processes in use, work shifts and breaks, and the design of the workstations used for packing. Practical considerations relevant to measurement, such as camera and video positioning and power supplies, and the availability of a location suitable for fitting subjects with the heart rate monitors were also dealt with.

Two versions of an information sheet to explain the project were written aimed at participating companies and participating workers. These were restricted to under two sides of A4 paper and were approved by the HSE REC. A consent form was also written for potential subjects and approved by the REC. This allowed subjects to indicate their willingness or otherwise to complete the questionnaire, have their heart rate monitored and their activities videoed, and for use in HSE publications of any still photographs or video footage that showed them. These forms are reproduced in Appendix 2.

The company information sheet was used to explain the project to the companies and multiple copies of the volunteer information sheet and the consent form were left with companies to distribute to potential participants.

Usually at this stage a date was agreed for a further visit to allow the measurements to be carried out over the course of a complete shift. In a few cases, in order to minimise travelling to distant locations, visits were combined so a preliminary visit was carried out on one day with the measurement visit on the following day. Also, where possible, visits to nearby plants were combined so that they took place on the same or adjacent days.

## 2.6. Accident reports

During the preliminary visits requests were made to examine the plant's accident book. This was done solely to identify accidents which had occurred to packers in the previous 12 months. Notes were made of the date of the accident and the nature of the accident.

## 2.7. Selection of subjects

The study protocol called for four packers at each site to be videoed and to have their heart rates monitored. It was made clear to companies and workers that participation was completely voluntary. No attempts were made to select workers for this monitoring except on the criterion of willingness to volunteer. The study was deliberately designed to maximise the acceptability to workers of the measurements by using lightweight, comfortable, heart rate monitors and by using unobtrusive videoing to record postures, and by using a simple to complete standard HSE questionnaire.

## 2.8. Completion of consent forms

On arrival at a plant where the completed consent forms had been completed in advance of the visit, these were obtained from the management and the volunteers willing to be monitored were identified. Where necessary, consent forms were completed at the start of the shift, and the workers willing to be monitored were fitted with the heart rate monitors. Where possible consent forms were checked for completeness and if questions had been missed this was checked with the subject. The question regarding use of photographs was often omitted. This may have been partly due to the layout of the consent form being different for this question than for other questions, but may also have been a result of workers being unwilling to allow their photographs to be used, but being unwilling to say so.

## 2.9. Survey of musculoskeletal 'trouble' using the HSE version of the Nordic Musculoskeletal Questionnaire (NMQ)

This was carried out as part of the measurement visit to each plant. The available packers at each site were asked to fill in the HSE version of the NMQ (see Appendix 2), normally during a morning break. An alphanumeric code was written on the questionnaires and the matching consent form to allow identification of the plant and the individual worker. Help was given to a few workers who said that they had not got their glasses with them. As the questionnaires were collected they were checked to ensure that all questions, particularly the questions regarding musculoskeletal disorders had been answered. On numerous occasions workers had accidentally omitted some of these questions and when this was detected the questionnaire was handed back to the worker with a request to complete the missing questions. Despite this checking process a few questionnaires were found afterwards to have an occasional uncompleted question. At one plant a few questionnaires were left with workers overnight, who then returned them the following day, or in one case, by post. Where more than one shift worked at a plant, efforts were made to get both shifts to fill in the questionnaire by staying on site until the second shift arrived, or returning the following day.

Data from the questionnaires were entered into a Lotus 123 spreadsheet, normally during the course of the visit, with the data from one subject being entered into one row. The spreadsheet was used to calculate ages from date of birth and date of completion of the questionnaire. Weights in stones and pounds were converted into kilograms. Heights in feet and inches were converted into cm. These figures were used to calculate Body Mass Index in $kg/m^2$. Data were grouped by plant. Descriptive statistics were calculated for individual plants, monorails and hand packing and for all plants.

## 2.10. Ratings of Perceived Exertion

The Rating of Perceived Exertion scale created by Borg (Borg, 1998) was used to obtain an overall rating of workers' perceptions of how strenuous their jobs are. The scale consists of integers from 6 to 20, with the odd numbers linked to verbal anchors of increasing levels of exertion from 'Very, very light' to 'Very, very hard'. The scale is reproducedin Appendix 2. It was copied onto the back page of the NMQ and workers completed it by marking a single value to indicate how hard they thought the job was overall.

## 2.11. Heart rate monitoring

### *2.11.1. Protocol for measurements*

Heart rates were monitored over the shift for up to four workers at each site using Polar Heart Rate Monitors (Polar Electro Oy, Kempele, Finland). Initially two Polar Vantage NV models and two Polar Sport Tester models were available. To increase the flexibility and reliability of the measurements two more Polar Vantage NV models were obtained soon after the start of the project. These particular models use 'coded transmission' so that the risk of cross-talk between watches and transmitters is reduced. They also have larger memories, allowing longer periods to be monitored at higher sampling rates. The Vantage NVs are simpler to use, and therefore using a single model reduced the risks of operator error by reducing the number and range of actions to be performed to record and download data. Using a single model also allowed the use of a single computer interface to download the data and eliminate the use of a Sports Tester with a separate sensor / transmitter which clipped onto a chest band with built in electrode areas. The Vantage NV consists of a 'Polar Coded Transmitter' with grooved electrode areas on the back which connects to an elastic chest strap. During the first measurement visit damage occurred to the strap of the wrist monitor of one of the Sports Testers. Subsequently, subjects were given a wrist sweat band to place over the Receivers to protect them from contact with the bricks.

Prior to each visit the watches were checked to ensure that their memories had been cleared and that they were all reading the correct time to within 1-2 seconds. The sampling period was set according to the expected length of the shift and the memory of the individual watch. Where possible, intervals of 5 s were used. On a few occasions, where the length of the shift would have exceeded the capacity of the Sports Tester models to record data at 5 s intervals, 15 s and 60 s intervals were used.

At the start of each measurement visit the workers willing to have their heart rates monitored and postures videoed were identified, and it was ensured that they had completed the appropriate sections of the consent form. The heart rate monitors were fitted according to the manufacturer's instructions, with the electrode grooves being wetted with tap water immediately before attaching the elastic chest straps and fitting the transmitter to the subject's chest. It was positioned centrally against the skin of the chest, approximately level with the base of the sternum, i.e., below any breast tissue, with the Polar logo upright. The strap was adjusted for length to ensure a tight but comfortable fit. The receiver was then set to record and held near the chest of the subject. Once it was confirmed that the receiver was receiving data from the transmitter it was handed to the subject to put on his wrist, with a sweat band to go over it.

At the end of the shift the receiver and transmitter were collected from the subject and recording stopped. The data were then usually immediately downloaded to a laptop computer (486 SX 25, 8 MB RAM, 120 MB HD) running version 2.0 of the Polar Precision Performance software under Windows 3.1, and a brief explanation of the output graph given to the subject, along with the mean heart rate over the period. After each visit the watches, transmitters, chest straps and sweat bands were washed to remove sweat and brick dust.

On a number of occasions problems were experienced with the HRMs, usually due to operator error. On the first visit this led to no data being collected from one subject and partial data from another. The two Sports Tester watches were initially set to record every 5 s. Part way through the shift they were reset to record every 15 s to ensure that they would not run out of memory. On this, and one other occasion, watches stopped by accident, and were then restarted. On the second visit the Sports Tester with the sensor / transmitter which clipped onto the separate chest band was used initially with disposable electrodes. It was realised early in the shift that these were not adhering to the subject's skin, so they were replaced with the chest band with the grooved electrodes on the rear surface. On one occasion the battery in one watch failed and no data were recorded from the subject wearing it. On another occasion, a watch memory had not been cleared and therefore part way into the shift it displayed a FULL message. The watch was therefore removed and the collected data downloaded before it was cleared and the watch returned to the subject for the remainder of the shift.

### 2.11.2. Data screening

One characteristic of the Polar HRMs, described in both the user's manual and the Software manual, is that occasionally drop outs occur in the data due to brief loss of contact between the skin and the transmitter. This appears as spuriously low readings, often zero. The other recognised problem is that signals from two transmitters can be picked up by a single receiver if both transmitters are not using coded transmissions. This results in spuriously high values, often in excess of physiologically possible values. These problems are particularly noticeable when every heart beat is being recorded, but less so when averages of intervals are being stored due to the nature of the averaging process. The software allows these artefacts to be removed by editing the data file. This was done by linear interpolation over the period deemed spurious using the adjacent values. An example of a heart rate trace before and after removal of these artefacts is given in Figures 1 and 2.

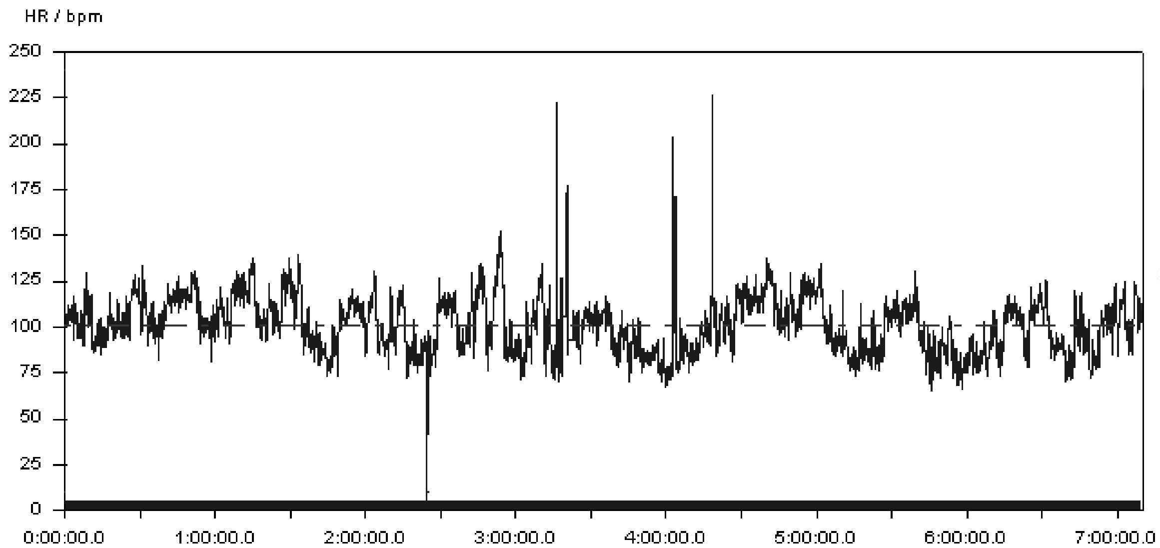


**Figure 1: Example heart rate curve showing artefacts**

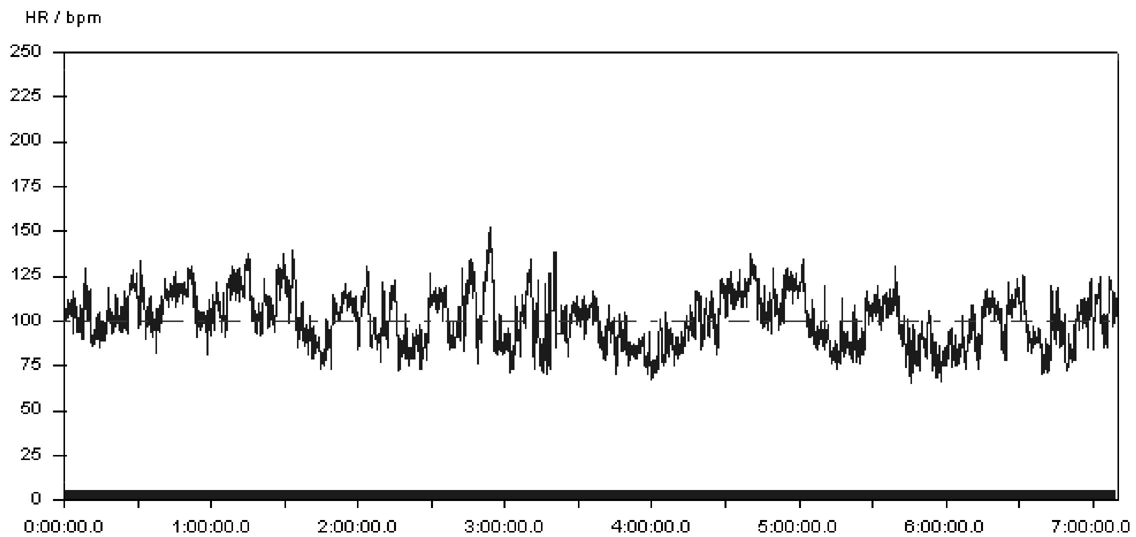


**Figure 2: Example heart rate curve after removal of artefacts**

### 2.11.3. *Analysis of heart rates*

Review of the literature on measurement and interpretation of working heart rates (e.g., Astrand and Rodahl, 1986) showed that much of the relevant scientific work was done in the 1950s and 1960s, before the current generation of measurement devices was available. It became clear that precise definitions of resting heart rate and working heart rate do not exist.

Resting heart rate has often been measured by asking the subject to sit down quietly for five minutes and then measuring the resultant heart rate. However resting heart rate depends on posture and the period of inactivity. Thus a heart rate measured in a lying down posture will be less than that measured if the individual is sitting, which will be less than if the individual is standing. No attempts appear to have been made to standardise posture or the length of rest in that posture. Nor has any attempt been made to decide between an instantaneous minimum value or an average over a period, and if an average is used what kind of variability should be accepted. Instead it has often been assumed that resting heart rate is 70 beats per minute, which is the default option in the Polar software. Palenciano *et al.* (1996) calculated resting heart rate of miners as the lowest average heart rate for three consecutive minutes of the recorded data.

Working heart rate has tended to be measured over a short period after about five minutes of the activity under study, by which time a steady state is assumed to have been reached. While this is convenient for laboratory studies of simple activities such as pedalling a cycle ergometer, it is not sufficient to characterise a complex manual handling task carried out by experienced workers over the course of a whole shift. In such a situation the load may vary according to the workstation that the worker is rotated through, and the basic cycle time required to deal with a pack of bricks may be much longer than five minutes.

For the purposes of this study, since it was obvious from the heart rate curves when subjects were taking rest breaks and when they were working, the resting heart rate was taken as the average of the visually found minimum in a rest break, over the longest period possible that would give a standard deviation of less than 5 beats per minute. Working heart rate was defined as the mean heart rate over a one hour period that did not include breaks. This period was selected visually from the graphs of heart rate against time. Maximum heart rate was estimated from the formula Max HR = 220 - age (Astrand and Rodahl, 1986). Heart Rate Reserve (HRR) was calculated as the difference between maximum heart rate and resting heart rate. Work Pulse (WP) was calculated as the difference between mean working heart rate and mean resting heart rate. Work Pulse was also expressed as percentages of the resting heart rate and the HRR. Also, the percentage of time during which the heart rate exceeded 40% and 50% of the HRR was calculated.

### 2.11.4. *Analysis of fatigue trends*

It was noted that in a few subjects there was a clear tendency for the general trend of the heart rate to increase over the duration of the work shift. This is traditionally seen as an indication of fatigue (Brouha, 1967, Astrand and Rodahl, 1986). Therefore the data were examined to see in which individuals a significant correlation existed between heart rate and time of day / stage of the shift. This was done by averaging the data over 30 minute periods, ending on the hour or half hour, and then carrying out linear regressions between the time of day and the heart rate to see if heart rate could be predicted from the time of day. For this purpose the middle point of the 30 minute period was used.

## 2.12. Posture analysis

### *2.12.1. Video recording.*

Two video cameras were set up at each plant. Composite video signals from the cameras were fed via long cables into two Panasonic AG5700 SVHS video recorders and recorded onto 4 hour SVHS tapes. Camera locations were chosen to give as good a field of view as possible of the areas where the packers being monitored would be working. On monorails the cameras were usually hung from the top of the machine, pointing down both sides. At the hand packing plants the camera directions were often changed to follow workers as they moved round the packing areas. No additional lighting was introduced into the plants as this would have presented large technical difficulties and it was desired to keep the observations as unobtrusive as possible. Therefore filming relied upon the lighting installed in the plants and daylight. Due to the time of year at which the visits were made and the very early starts of some shifts much filming took place before daylight was available.

Due to the length of time needed to set up the cameras, recording often started after the start of the shift. Where time and security considerations allowed, equipment was set up the previous night. At two hand packing sites it was found that workers had arrived and started work considerably earlier than the official shift start time and therefore this earlier period was also lost. The tapes were left recording continuously and were not stopped during breaks. When tapes were full they were immediately replaced by fresh tapes. Depending on the length of shift, between one and three tapes were recorded from each camera at each plant. Cameras were numbered 1 and 2; films were numbered sequentially from 1 upwards. Starting times, to the nearest second, were written on the labels of all tapes.

At Plants 11 and 12 'Vertical Interval Time Codes' (VITC) were added to the composite signals from the camera by feeding the signals through AEC BOX 18 VITC generators (Adrienne Electronics Corporation, Las Vegas, Nevada, USA) before they were fed to the video recorders. These time codes are inserted in the vertical intervals on the video tape between successive video fields in an hh:mm:ss:cc format and are accurate to 0.02 s. For the other plants VITC signals were added as the original tapes were copied onto new tapes. A double pole non-latching push-button switch was wired to the RESET inputs of the 'Options' connectors of the two VITC generators to allow simultaneous resetting of both generators. The times at which the VITC generators were reset were recorded on the tape labels to the nearest second. Normally this was done at the end of a full minute or half minute.

### *2.12.2. Posture coding*

Video tapes from four plants were coded using the OWAS system (Karhu *et al*., 1977, 1981, Vedder, 1998). This was done using the Observer Pro video analysis system (Noldus Information Technology BV, Wageningen, The Netherlands) to provide precise control of the video tape (Carey and Gallwey, 1998) while postures were being coded, and the WinOWAS software (Tampere University Technology, Occupational and Safety Engineering, 1996) to allow assessment of the coded postures.

V4.0 of the Observer Support Package for Video Analysis was used on an IBM compatible PC running Windows 95. This was connected to a Panasonic AG7350 SVHS video recorder via a Panasonic AG-IA232 TC video controller which controlled the video recorder via the serial port of the computer. The computer was also connected to the VCR via an AV PCL5V time code reader board (Alpermann + Velte Electronic Engineering GmbH, Wuppertal, Germany) which read the VITC codes from the video signal from the tape to half-frame accuracy (0.02 s). The video signal was also fed via an MCI compatible 'Screen Machine II' video overlay board (FAST Multimedia AG, Munich, Germany) which allowed real-time display of the video picture on the computer monitor.

The Observer software was set up to allow 'instantaneous sampling', i.e., sampling at fixed intervals. This method is also known as 'time-lapse sampling' or 'occurrence sampling' (Vedder, 1998). The interval chosen was 1 minute, with a timing resolution of 0.01 s. A single independent variable was set up which was a three or four digit code based on the plant number, camera number and film number. Four Subjects were defined to correspond to the four subjects whose heart rates were being monitored. Four Behavioural Classes were defined corresponding to the three body parts and force level category that are classified in the OWAS system. Within each Behavioural Class, Elements were defined corresponding to each of the postures for the corresponding body part. A 'no entry' element was also defined for each body part. Each Element was assigned to a different keystroke to allow rapid coding via the computer keyboard. This combination of Subjects, Behavioural Classes and Elements allowed each of the four subjects being observed to be coded separately at each sampling point. The Behavioural Classes and Elements are listed in Table 4:

**Table 4: Assignment of postures to Behavioural Classes / Elements**

| Behavioural Class | Element | Definition | Code no | Keystroke | |
|---|---|---|---|---|---|
| Back | STRAIGHT | Trunk upright and not rotated | 1 | Q | Default |
| | BENT | Trunk flexed | 2 | W | |
| | TWISTED | Trunk rotated | 3 | E | |
| | B&TW | Trunk flexed and rotated | 4 | R | |
| | NOBACK | Trunk not visible | 5 | T | |
| Arms | 2BELOW | Both arms below shoulders | 1 | A | Default |
| | 1ABOVE | 1 arm above shoulders | 2 | S | |
| | 2ABOVE | Both arms above shoulders | 3 | D | |
| | NOARMS | Arms not visible | 4 | F | |
| Legs | SITTING | Both limbs unloaded | 1 | X | |
| | STAND2 | Loading on both limbs, straight | 2 | Z | Default |
| | STAND1 | Loading on one limb, straight | 3 | C | |
| | 2 BENT | Loading on both limbs | 4 | V | |
| | 1 BENT | Loading on one limb, bent | 5 | B | |
| | KNEEL | Loading on one limb, kneeling | 6 | N | |
| | WALK | Body is moved by the limbs | 7 | M | |
| | NO LEGS | Legs not visible | 8 | \ | |
| Load | <10 KG | Load < 10 kg | 1 | I | Default |
| | <20 KG | Load between 10 kg and 20 kg | 2 | O | |
| | >20 KG | Load > 20 kg | 3 | P | |
| | MISSING | Subject not visible | 4 | Y | |

### *2.12.3. Posture analysis*

Two hand packing sites and two monorails were selected for detailed coding. These were plants 2, 4, 10 and 11. The occurrence of the first real time full minute or half minute was selected as the start point for coding. The postures of subjects who were visible and whose heart rates were being monitored were coded. Where necessary, the tape was replayed or shuttled to determine the motion that the subject was performing at the moment of coding. Thus, if a subject was carrying out a twisting movement, but had an untwisted trunk at the moment of coding, he was coded as having a twisted trunk. The load at the hands was assessed by multiplying the number of bricks being handled by the known weight of the bricks (given in Table 9). Where a subject was observed to be moving towards the kiln pack in order to pick up bricks the load was assessed as being zero even if the hands could not be seen. It should be noted that the coding system does not distinguish between zero load and loads less than 10 kg.

Once postures at one sampling point had been coded the tape was then advanced by one minute under computer control and the postures recoded. Where workers were absent from the packing workstations, missing codes were entered for them, particularly during breaks.

On occasions, due to problems in camera placement and ambient lighting conditions, picture quality was poor. Therefore, at Plant 4, where a relatively short period of good quality film was obtained, this was sampled every 20 seconds to increase the number of postures sampled.

Once the end of the tape was reached a file was saved in the Observer .ODF format, which is a type of text file. An example of part of one of these files is included in Table 7.

After all the selected tapes had been coded, the .ODF files for each plant were joined together by importing them into a spreadsheet and aligning them against real times. The spreadsheet was used to convert the text Element Names saved by The Observer into the four digit numeric codes required by the OWAS software (see Table 4 and Table 7). The outputs from the two cameras were then combined to group the codings for the four subjects. Especially at plants, such as the monorails, where the workers moved round between workstations, this was necessary to ensure that codings of the same worker at different points in the work shift were grouped together. Codings of missing values, e.g., from when the workers were on a break, were omitted, so that the assessment depended solely on the observed postures at the packing stations. The OWAS Action Categories (AC 1 to AC 4) are shown in Table 5.

**Table 5: OWAS Action Categories**

| Action Category | Meaning | Action required |
|---|---|---|
| 1 | Normal posture | No action required |
| 2 | Slightly harmful posture | Action required in the near future |
| 3 | Distinctly harmful posture | Action required as soon as possible |
| 4 | Extremely harmful posture | Action required immediately |

A fifth digit was added to each code to identify the different subjects. The codes were then output from the spreadsheet into a text file in the .OWS format required for input into the WinOWAS program. This consists of a short header identifying subjects, and the number of items in the file, followed by the five digit codes. Part of such a file is shown in Table 8:

The WinOWAS software was then used to convert the sampled data into OWAS Action Categories. This was done separately for each plant and also for the combined data from the four plants.

### *2.12.4. Assignment of postures to Action Categories*

The WinOWAS software (Tampere University Technology, Occupational and Safety Engineering, 1996) implements an algorithm which assigns Action Categories on the basis of the percentage of time that a person spends with a body part in a particular posture. This allows different degrees of severity to be assigned to the same posture, depending on the proportion of the time that is spent in any particular posture, and is a substantial refinement of the original classification system (Karhu *et al*., 1977) which assigned postures to Action Categories irrespective of whether they were frequently adopted or only rarely adopted. The meanings of the different Action Categories were given in Table 5. The postures, percentages of time and associated Action Categories are listed in Table 6.

**Table 6: Percentages of time in a posture and assignment to Action Categories**

| Body part | Posture | AC 1 | AC 2 | AC 3 | AC 4 |
|---|---|---|---|---|---|
| Back | Straight | 0-100% | | | |
| | Bent | 0-30% | 30-80% | 80-100% | |
| | Twisted | 0-20% | 20-50% | 50-100% | |
| | Bent and Twisted | 0-5% | 5%-30% | 30-70% | 70-100% |
| Arms | Both below shoulder | 0-100% | | | |
| | One below shoulder | 0-30% | 30-80% | 80-100% | |
| | Both above shoulder | 0-20% | 20-70% | 70-100% | |
| Legs | Sitting | 0-90% | 90-100% | | |
| | Standing on two legs | 0-80% | 80-100% | | |
| | Standing on one leg | 0-30% | 30-80% | | |
| | Standing on two bent knees | 0-5% | 5-30% | 30-70% | 70-100% |
| | Standing on one bent knee | 0-5% | 5-30% | 30-70% | 70-100% |
| | Kneeling | 0-20% | 20-50% | 50-100% | |
| | Walking | 0-80% | 80-100% | | |
| Load | < 10 kg | 0-100% | | | |
| | < 20 kg | 0-100% | | | |
| | > 20 kg | 0-100% | | | |

## Table 7: Example of part of an output file from The Observer Video Analysis Module v4.0 with conversion to input format for WinOWAS software

| Output file | Meaning | | | | | | |
|---|---|---|---|---|---|---|---|
| BRICKS.CNF | [Name of Observer Configuration File] | | | | | | |
| Plant 2 coding 3/6/99 | [Text comment] | | | | | | |
| 06-03-1999 | [Date of coding] | | | | | | |
| 01:33:30.00 | [VITC code at start of sampling] | | | | | | |
| {media} | | | | | | | |
| 211 | {Plant, camera, film} | | | | | | |
| | | | | | | | |
| {indvar} | | | | | | | |
| 211 | [Plant, camera, film] | | | | | | |
| {start} | | **Code** | **S1** | **S2** | **S3** | **S4** | **True time** |
| 0.00 s1,STRAIGHT | [Time offset in s, subj. no, back posture] | 1 | 1,121 | 1,122 | 2,142 | 0 | 08:18:00 |
| 0.00 s1,2BELOW | [Time offset in s, subj. no, arms posture] | 1 | | | | | |
| 0.00 s1,STAND2 | [Time offset in s, subj. no, legs posture] | 2 | | | | | |
| 0.00 s1,<10KG | [Time offset in s, subj. no, load handled] | 1 | | | | | |
| 0.00 s2,STRAIGHT | | 1 | | | | | |
| 0.00 s2,2BELOW | | 1 | | | | | |
| 0.00 s2,STAND2 | | 2 | | | | | |
| 0.00 s2,<20KG | | 2 | | | | | |
| 0.00 s3,BENT | | 2 | | | | | |
| 0.00 s3,2BELOW | | 1 | | | | | |
| 0.00 s3,2 BENT | | 4 | | | | | |
| 0.00 s3,<20KG | | 2 | | | | | |
| 0.00 s4,NOBACK | | 0 | | | | | |
| 0.00 s4,NOARMS | | 0 | | | | | |
| 0.00 s4,NO LEGS | | 0 | | | | | |
| 0.00 s4,MISSING | | 0 | | | | | |
| 60.00 s1,STRAIGHT | | 1 | 1,322 | 1,151 | 2,142 | 0 | 08:19:00 |
| 60.00 s1,2ABOVE | | 3 | | | | | |
| 60.00 s1,STAND2 | | 2 | | | | | |
| 60.00 s1,<20KG | | 2 | | | | | |
| 60.00 s2,STRAIGHT | | 1 | | | | | |
| 60.00 s2,2BELOW | | 1 | | | | | |
| 60.00 s2,1 BENT | | 5 | | | | | |
| 60.00 s2,<10KG | | 1 | | | | | |
| 60.00 s3,BENT | | 2 | | | | | |
| 60.00 s3,2BELOW | | 1 | | | | | |
| 60.00 s3,2 BENT | | 4 | | | | | |
| 60.00 s3,<20KG | | 2 | | | | | |
| 60.00 s4,NOBACK | | 0 | | | | | |
| 60.00 s4,NOARMS | | 0 | | | | | |
| 60.00 s4,NO LEGS | | 0 | | | | | |
| 60.00 s4,MISSING | | 0 | | | | | |

**Table 8: Example of part of an *.OWS file for input to the WinOWAS software**

| File Entry | Meaning |
|---|---|
| !OWAS! | [File identifier] |
| ”” | |
| ”” | |
| ”” | |
| ”” | |
| ”” | |
| ”” | |
| 4 | [Number of subjects] |
| “P21” | [Subject 1] |
| “P22” | [Subject 2] |
| “P33” | [Subject 3] |
| “P44” | [Subject 4] |
| 60 | [Sampling interval in seconds] |
| 1215 | Number of samples in file |
| 11210 | Code for Back, Arms, Legs, Load and Subject |
| 41210 | |
| 11210 | |
| 41420 | |
| 11210 | |
| 41410 | |
| … | |
| 31213 | |
| 31213 | |
| 41423 | |
| 41513 | |
| 41423 | |
| 11213 | |

## 3. RESULTS

### 3.1. Plants visited

A total of 12 plants were visited between November 1998 and January 1999. These belonged to a total of five firms. The number of plants visited per firm ranged between one and three. Plants are identified only by an alphanumeric code to ensure a degree of anonymity between them.

### 3.2. Summaries of information about the plants visited

In order to allow easy description of the wide range of information gathered about the different plants it has been summarised into a number of tables.

Table 9 gives details of the kilns in use and the types of bricks produced, the kiln pack setting method, where known, typical brick weights, whether the plant used hand packing or monorails and the maximum brick lift (MBL) in force. The details of the kiln and brick types and the typical brick weights give information about the nature of the bricks being handled. The kiln pack setting method (where known) gives background information about whether other manual handling is involved in brick production. The packing method and MBL information relate to how plants were selected for inclusion in the study.

Table 10 give details of the designs of the kiln packs and the despatch packs. Kiln pack sizes are given as a number of brick lengths deep and wide. The number of bricks widths across when bricks are crossed in the other orientation is given in brackets. Figure 9 shows a kiln pack with two layers of bricks in one direction followed by two crossed layers in the other direction. Despatch pack widths and heights are given assuming that the bricks are set on edge and end on, as in Figure 4. Despatch packs depths are described in terms of ‘blades’, that is, the number of brick lengths the pack is deep. Monorail jigs are all two blades deep, but the strapping head of the monorail forms a pack five blades deep from a line of blades of bricks pushed out of the jigs by a hydraulic ram. This table therefore gives an indication of the numbers of bricks to be handled and their layout, and the size of the destination pack into which bricks are to be placed. This information can be used to assess the maximum and minimum heights that bricks are packed to and from and the horizontal reaches and brick orientations involved, both of which affect the handling methods used.

Table 11 gives details of the packing and strapping methods in use, including the destinations of seconds and waste. These also affect the handling methods used and the postures needed to dispose of the seconds and waste. The strapping method gives an indication of whether packers are solely handling bricks or whether there are other tasks that they have to carry out as well, such as putting bags over complete packs of bricks.

Table 12 give details of the work shifts in operation at the times of the visits. This indicates how the exposure of workers to manual handling is spread out over the week and whether circadian rhythms (daily changes in body temperature, etc.), might be expected to have an effect due to shift working.

Table 13 gives details of the output targets as daily and hourly rates and the actual hourly rates achieved. This indicates the notional rate at which packers work and the actual rates at which they work. It is important to express packing rates as hourly rates because of the variations in shift length and number of days worked in a week on different shift systems would make comparison of daily or weekly loads invalid.

## 3.3. Site visits / discussion with company representatives and workers

The importance of a wide variety of issues was highlighted during visits, particularly in discussions during the visits. A number of these are detailed below.

### *3.3.1. Nature of the industry*

The general trend over the last several decades has been towards mechanisation in the industry throughout the production process. The increased ease of transport has led to a reduction in the number of operating plants and a tendency to sell to larger areas. Some plants had cut production by eliminating second shifts or by demolishing kilns. Overall, stock levels appeared to be quite high, with plants often having several months production in stock.

There have been numerous changes in ownership of a number of plants with larger firms tending to grow by acquiring smaller ones. The Monopolies and Mergers Commission forced one of the larger firms to divest plants because it was seen as over dominant in the industry. The impression gained was that the industry is open with staff moving between firms and firms seemed generally willing to share information with each other.

### *3.3.2. Packaging methods*

Bricks are universally packaged into despatch packs which are designed to be handled by fork lift trucks. Each 'blade' of the pack is held together by steel or plastic strapping (Figure 3). The four or five blades that make up the pack are held together by plastic corners fitted to the pack or occasionally with cross-strapping. Holes for the tines of fork lift trucks are left in packs near the bottom (Figure 4). The size and design of packs vary depending on the pack width and the orientation of the bricks. In some packs bricks are placed face to face to protect the faces. In other plants sheets of paper are placed between layers of bricks to protect the faces. Pieces of hardboard or plastic are usually placed over the layer where the spaces are left for the fork lift tines to help hold the pack together.

Traditionally, galvanised mild steel strapping has been used. This has good working properties which allow it to be tensioned and to be bent to fit the packs. Strapping can either be done by an automatic strapping head or with a hand strapping device where the strapper feeds the strapping round the pack and through the strapping device and then uses a ratchet handle to get the desired tension. If excessive tension is applied the strapping will break. Therefore the wearing of goggles while hand strapping is widespread to protect the eyes from flailing ends of strapping.

**Table 9: Kiln and brick details**

| Plant | Kiln type | Brick type | Kiln pack setting method | Typical brick weight | Packing method | Maximum Brick Limit (MBL) |
|---|---|---|---|---|---|---|
| P1 | Two tunnels, with moving fire | Wire cut, with holes | Machine | 1.9 - 1.95 kg | Monorail | 5 |
| P2 | Tunnel; bricks on kiln cars | Wire cut, with holes | Machine | 2.5 kg | Monorail | 4/5 |
| P3 | Wire cut: tunnel, bricks on kiln cars, Hand made: intermit-tent kiln | Wire cut, with holes; solid hand made | ? | 2.5 - 3.0 kg | Monorail | None |
| P4 | Tunnel, bricks on kiln cars | Wire cut, with holes | Machine | 2.4 - 2.6 kg | Hand packing | None |
| P5 | Hoffmann, with square roofs | Solid, engineering bricks and pavers | ? | 3.2 kg and 2.7 kg | Hand packing | 2 |
| P6 | Hoffmann, with square roofs | Solid, 'reclaims' | ? | 2.3 kg | Monorail | 5/6 |
| P7 | Two Hoffmann with arched roofs | Pressed, with frog | Machine | 1.8 kg | Hand packing | None |
| P8 | Four Hoffmann with arched roofs; one out of use | Pressed, with frog | Hand | 1.8 kg | Hand packing | None |
| P9 | Hoffmann, with square roofs | Pressed, with frog | Machine, 4 blades set together | 2.1 kg | Hand packing | 3 (ignored) |
| P10 | Hoffmann, with arched roofs and narrow entrances | Wire cut, with holes | Hand; some restacking in kilns | 2.2 kg | Monorail | 2 |
| P11 | Tunnel, bricks on kiln cars | Wire cut, with holes | ? | 2.5 kg | Monorail | 4/5 |
| P12 | Tunnel, bricks on kiln cars | Pressed, with frog, and heavily sanded | Machine | 2.3 kg | Hand packing | 4 |

## Table 10: Kiln pack and despatch pack designs

| Plant | Kiln pack design | Despatch pack design |
|---|---|---|
| P1 | 13 high: 1120 per pack, set on edge, 4 (12) deep, 4 (12) wide × 2; 14 high: 1156 per pack; 11 set on edge, 4 (12) deep, 4 (12) wide × 2, + top 3 set on beds, 4 deep, 7 wide | 430 in pack; jigs 2 blades deep, 10 across, 9 high |
| P2 | 15 high, set on edge, 4 (9/11) wide, 4 (9/11) deep; 8 bottom layers aligned in pairs, top layers crossed | 380 in pack; jigs 2 blades deep, 10 across, 8 high |
| P3 | Wire cut: 17 high, 10 on edge, 2 on beds, 2 on edges, 3 on beds; top 5 layers shaped for kiln; 4 (9) deep, 10 (22/26) across. Solids: 17 high, 9 on edges, 1 on beds, 2 on edges, 1 on beds, 2 on edges, 2 on beds; 4 (9) deep, 10 (22/26) across. Layers on edge aligned in pairs. | 380 in pack; jigs, 2 blades deep, 10 across, 8 high |
| P4 | 560 in pack, 14 high, set on edge, 4 (10) across, 4 (10) deep; 3 packs per car. | 515 in pack; 5 blades deep, 13 across, 9 high, 2 layers on edge, 1 on beds, 3 on edge, 1 on beds, 2 on edge |
| P5 | Bricks: 17 high, on beds, 4 (5/7) across, 4 (5/7) deep; 14 high, 6 on edges, 2 on beds, 4 on edge, 2 on beds, 4 (9) across, 4 (9) deep. Pavers: 14 high, 4 on edge, 2 on beds, 3 on edges, 2 on beds, 3 on edges, 4 (5/7) across, 4 (5/7) deep. | Bricks: 400 in pack; 4 blades deep, 13 across, 10 high, 2 on edge, 2 on beds, 1 on edge, 2 on beds, 1 on edge, 1 on beds, 1 on edge. Pavers: 450 in pack, 5 blades deep, 11 across, 14 high, 2 on edge, 12 on beds |
| P6 | 12 high, set on edge, 4 (11) across, 4 (11) deep | 440 in pack; 5 blades deep, 10 across, 10 high, 2 on edges, 1 on beds, 3 on edges, 1 on beds, 3 on edge |
| P7 | 1170 / block. Two halves. Base: Leg bricks on end, + 9 on edges. Top: shaped to fit kiln: 13 high on edges; or 1 on edge, 18 on beds. | 390 in pack; 5 blades deep, 10 across, 9 high, 1 on edge, 1 on beds, 1 on edge, 1 on beds, 5 on edges |
| P8 | 1170 / block Two halves. Base: Leg bricks on end, + 9 on edges 4 blades deep, 8.5 wide; top is shaped to fit kiln: 4 blades deep, 8 across, 13 high on edges; or 1 on edge, 18 on beds. | 390 in pack; jigs 2 blades deep, 10 across, 9 high, all on edges except layers 2 & 4 on beds |
| P9 | Two halves. Base: 10 high on edges, 2 blades deep, 11 (39) across; Top: 10 high, on edges, 2 deep, 10 (36) across; no ties between blades | 370 in pack; 5 blades deep, 10 across, 9 high, 1 on edges, 1 on beds, 1 on edges, 1 on beds, 2 on edges, 1 on beds, 2 on edges |
| P10 | Usually 8 high, on edges, 4 (13) deep by 4 (13) across | 500 in pack; 5 blades 13 across, 8 high on edges |
| P11 | 12 high, set on edge; 4 (10) deep, 4 (10) across | 380 in pack; jigs 2 blades deep, 10 across, 8 high |
| P12 | 16 high, set on edge; 4 (10) deep, 4 (10) across; 3 × 2 towers (3936 bricks) per kiln car | 500 in pack; jigs 2 blades deep, 13 across, 8 high |

## Table 11: Details of packing methods

| Plant | Packing from | Packed to | Seconds destination | Waste destination | Strapping method | Notes |
|---|---|---|---|---|---|---|
| P1 | Kiln pack on monorail platform | Monorail jigs, base 530 mm above platform | Pockets on both sides of monorail jig | Top of monorail jig | Steel, hand strapping by operator | |
| P2 | Kiln pack on monorail platform | Monorail jigs, base approx. 600 mm above platform | Pockets on both sides of monorail jigs | Top of monorail jig | Steel, automatic strapping head | |
| P3 | Kiln pack on kiln bricks on monorail platform | Monorail jigs, base approx. 600 mm above platform | Pockets on right hand side and top of jig | Conveyor under monorail | Steel, automatic strapping head | |
| P4 | Kiln cars passing under jigs | Jigs | Seconds jig, shared between two packers | Conveyor | Plastic, air powered hand strapping, | 3 layers below platform level; 2.5% rejects, < 1% waste |
| P5 | Kiln packs on platform | 4 jigs 160 mm above platform | Jig | Conveyor under platform | Steel, manual hand strapping | Paver layers separated by plastic on roll. |
| P6 | Kiln packs on floor | 160 mm high trays on floor | ? | Skip | Steel, manual hand strapping | 2% rejects, 1% waste; packs bagged by strappers |
| P7 | Kiln packs on ground adjacent to 1200 mm high walls | Hand packing using walls | Seconds pack | Ground between walls | Plastic, manual hand strapping | 10% waste |
| P8 | Kiln packs on monorail platforms and ground adjacent to walls | 2 monorails, base approx. 600 mm above platform + hand packing on walls | Conveyors under monorail | Conveyors under monorail | Plastic, automatic strapping head | 10% waste; Seconds removed from rejects on monorail 1 |
| P9 | Half kiln pack, 2 blades deep on stand 530 mm above platform | 2 jigs 400 mm above platform | No seconds if packed ATR (as they rise) | Skip under platform | Steel, air powered hand strapping | |
| P10 | Pack on 510 mm high tray on platform | 4 jigs 150 mm above 180 mm high platform | Jig | Skip | Steel; testing plastic, manual hand strapping | Presorting as bricks restacked from kiln to trays |
| P11 | Kiln pack on monorail platform | Monorail jigs, base approx. 600 mm above platform | Pockets on both sides of monorail jig | Floor & top of monorail jig | Steel, automatic strapping head | |
| P12 | Kiln cars passing under monorail | Monorail jigs, base approx. 650 mm above platform | Not packing seconds | Conveyor under monorail | Plastic, automatic strapping head | 2 layers below platform level; packers work in pairs |

**Table 12: Details of work shifts**

| Plant | Shift pattern | Shift start time | Shift finish time | Official shift length | Actual shift length |
|---|---|---|---|---|---|
| P1 | Single shift, Mon to Fri | 08:00 | 16:45; can leave 1 hour early | 8.75 hrs inc 0.75 hrs breaks; 43.75 hrs per week | 7.75 hrs; 38.75 hrs per week |
| P2 | Two shifts, four days on, four off | 06:00 | 17:30 (M-F), 17:15 (Sa-Su) | 11.5 hrs (M-F) 11.25 hrs (Sa-Su) inc breaks; average 40 hrs per week | |
| P3 | Single shift, Mon - Fri | 07:00 | 15:45 (M-Th) 13:30 (F) | 8.45 hrs (M-Th); 6.5 hrs (F) inc 1.25 hrs breaks; 41.5 hrs per week | |
| P4 | Two shifts, morning and afternoon, Mon - Fri; rotate weekly | 06:00 / 1400; Actually 05:15 / 11:00 | 14:00 / 20:00; Actually 11:00 / 15:30 | 8 hours, inc breaks; 40 hrs per week | 5.75 hrs; 28.75 hrs per week |
| P5 | Single shift, Mon - Fri & Sat am | 07:00 | 15:00; Actually 13:15 M-F | 8 hours inc breaks; 40 hrs per week | 6.25 hrs; 31.25 hrs per week |
| P6 | Single shift, Mon - Fri | 04:00 | 12:00 | 8 hours inc breaks; 40 hrs per week | 7 hrs; 35 hours per week |
| P7 | Single shift, Mon - Fri | 06:00 | 15:30 (M-W), 14:30 (Th), 10:00 (F) | 9.5 hrs (M-W). 8.5 hrs (Th), 4 hrs (F), inc breaks; 41 hrs per week | |
| P8 | Two shifts: Morning Mon - Fri; After-noon, Mon - Thu, rotate weekly | Morning 06:00 M-F. After-noon 14:30 M-Th | Morning 14:30; Afternoon 00:30 Tu-F | Morning 8.5 hrs inc breaks; 42.5 hrs per week. Afternoon 10 hrs inc breaks; 40 hrs per week | |
| P9 | Two shifts, 4 days on, 4 off | 07:30 (Some actually 07:00) | 18:30 (some actually 18:00) | 11 hrs inc breaks; average 38.5 hrs / week | |
| P10 | Single shift, Mon - Fri | 08:00 | 17:00 | 9 hrs inc 1 hr breaks; 45 hrs per week | |
| P11 | Single shift, Mon - Fri | 07:30 | 15:00 | 7.5 hrs inc breaks; 37.5 hrs per week | |
| P12 | Two shifts; 2 days on, 2 off, 3 on, 2 off, 2 on, 3 off | 07:00 | 18:30 | 11.5 hrs inc breaks; average 40.25 hrs per week | |

## Table 13: Details of packing rates

| Plant | No of packers | Output target per packer | Target hourly output | Actual hourly output | Notes |
|---|---|---|---|---|---|
| P1 | 6 + monorail operator | 12,500 / day | 1,562 | 1,786 | Can leave 1 hour early |
| P2 | 8 + monorail operator | 14,500 / day | 1,260 | 1,260 | |
| P3 | 10/11, inc 1 on rejects | 13,000 / day | 1,600 | 1,600 | |
| P4 | 5 per shift | 14,000 / day | 1,750 | 2,550 | Job and Finish |
| P5 | 12 | 11,200 (M-Th) 10,000 (F) 4800 (Sa) | | 1,792 | Job and Finish |
| P6 | 4.5 | 12,320 / day | 1,540 | 1,760 actual | Job and Finish |
| P7 | 32 | 44 blocks / week; (1170 bricks per block) | 1,320 | mean 1,650 (55 blocks per week) | Piece work |
| P8 | 11 per shift per monorail + hand packers | Morning 16000 / day; Afternoon, 18,000 / day | Morning 1882; Afternoon 1818 | Morning 1882; Afternoon 1818 | |
| P9 | 11 per shift | 13,200 / day | 1,200 | 1,200 | |
| P10 | 8 | 10,000 / day | 1,250 | 1,250 | |
| P11 | 7 + monorail operator | 22 cars / day 11,429 / day | 1,524 | 1,524 | |
| P12 | 6 per shift | 15,500 / day | 1,350 | 1,350 | |

Despite the galvanising, steel strapping will eventually corrode and break and appears to have a typical life of 18 months in a stockyard. Partly because of this problem, the industry is moving toward using plastic strapping but this has the disadvantage that it is more difficult to tension adequately and requires more complex strapping tools. Both types of strapping were seen in use, both in plants using automatic strapping and those using hand strapping.

In some plants the complete packs are then covered in plastic bags, usually labelled with the company name, which are shrink-wrapped to fit.

**Figure 3: Hand strapping of bricks with an air powered strapping tool.**

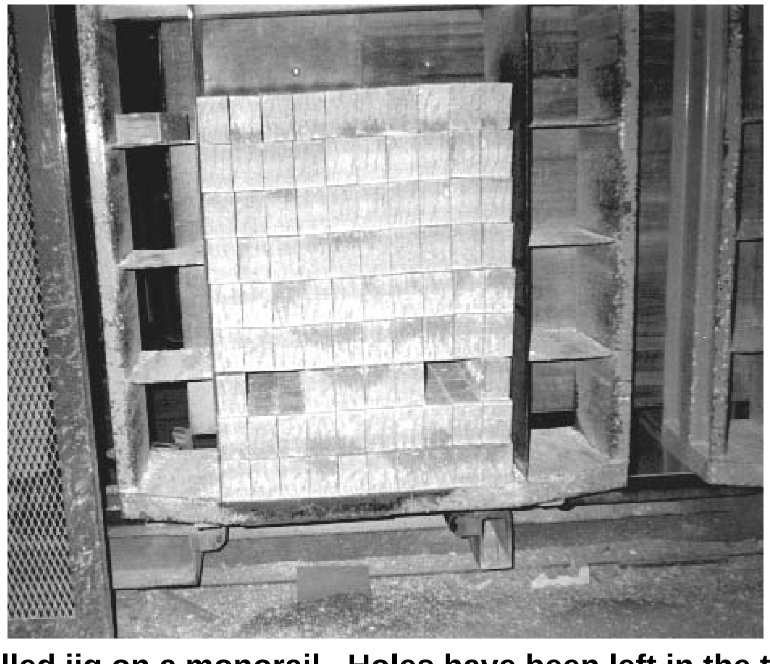

**Figure 4: A filled jig on a monorail. Holes have been left in the third layer for fork lift tines.**

### *3.3.3. Shift systems*

Table 12 reveals that there were a wide variety of shift systems in operation at the plants visited. The variety arises because seven day packing occurs in some plants. As kiln operation methods inevitably lead to production being continuous, seven day packing prevents the build up of unpacked bricks during weekends. Some of the shift systems in operation lead to long days, sometimes approaching twelve hours. Care has clearly been taken to construct systems which are acceptable to workers in terms of the numbers of weekends worked and the frequency they are worked. Also, on five day working weeks there is a general tendency to create a shorter day on Fridays to allow a longer break at the weekend. In the plants where two shifts work on the same day the shifts do rotate so that the demands for early starts and late finishes are balanced. At Plant 12 a ‘two days on’, ‘two days off’ system had been developed to spread the load so that packers were not continuously exposed to the stresses of packing. It also had the advantage of rotating fortnightly, allowing the packers to have a three day weekend off every other weekend.

### *3.3.4. Rate of packing*

The target rates for packing varied from 1200 bricks per hour to 1750 bricks per hour but actual rates reached 2250 bricks per hour (Table 13). It appears that a target of 1350 bricks per man hour was adopted some time ago by part of the industry, but information on how this figure was arrived at has not been obtained.. The target rates per shift ranged from 10000 to 18000, which is similar to the range from 8000 to 18000 reported by the BCC (1998). The BCC survey did not report shift lengths so it is impossible to compare hourly rates.

### *3.3.5. Training of packers*

Training of packers is largely informal and on the job. New starters are usually given lower targets to meet for an initial period while they get accustomed to the work. During this initial period they are also expected to learn the different types of brick being produced and the sorting criteria which determine whether bricks are ‘best’, ‘seconds’ / ‘commons’ / ‘rejects’ or ‘waste’ / ‘scrap’. On monorails they are usually introduced as an extra worker and expected to handle fewer bricks per cycle. Depending on the pay system they may be on a lower wage initially or a guaranteed basic if on piece work. The general consensus is that new workers will leave quite rapidly if they decide they do not like the work. In fact packers with less than a week’s experience were found in two plants.

### *3.3.6. ‘Warming up’*

A repeated feature of discussions with packers was the need for them to keep their muscles ‘warmed up’ while packing. The human body controls its core temperature quite closely. If the ambient temperature drops workers will increase their clothing or activity to compensate or turn on heating appliances. If the temperature increases they will remove clothing and increase ventilation, and will sweat more and therefore drink more fluids. Localised cooling of muscles through excessive air movements will decrease the efficiency of the muscles and increase the likelihood of injury. At one plant the packers complained that the ventilation system installed produced very localised jets of cold air which cooled their muscles if they were directly beneath them. At another, where bricks were being packed onto trays on the floor, packers said that they preferred to get into a stooped posture and stay there for a while because it allowed them to keep the muscles warm.

### *3.3.7. Postures while packing*

It was clear that packers have strong opinions on the best ways of doing their work in terms of posture. It has proved very difficult for plants to implement maximum brick lifts of 2 because of the need for more lifts to be carried out. It is clear that packers learn to move their body weight as they transfer bricks from the kiln pack to the despatch pack. Very often they will prefer to keep their feet almost stationary and use a combination of twisting, leaning and movement of the arms across the front of the body to execute the transfer. They will start the lift with the weight on the foot nearer the kiln pack and then swing and transfer the weight to the foot nearer the kiln pack as the hands take the bricks across the body. They will do this in preference to moving their feet. This can almost certainly be attributed to this method being quicker and requiring less energy.

### *3.3.8. Wrist problems*

Consistent reports of problems in the wrists were heard at several plants. The location was very specific to the region on the side of the wrist just behind the thumb. (In anatomical terms, this is the radial side of the wrist). The problem was attributed to pushing bricks together into groups of four or five so that they could be picked up by pressing them between the two hands. This action forces the hands to be bent both backwards and in the direction of the thumb at the same time. In anatomical terms this is described as forcing the wrists into flexion and radial deviation. It was noted that some packers did say that they tend to tip the pile of bricks so that most of the weight rests on one hand (Figure 5). The other hand then helps keep the stack together and prevents it from falling. This will decrease the force needed to keep the group of bricks together but will increase the weight carried by one hand and decrease the weight carried by the other.

**Figure 5: Hand packing from kiln packs on the floor to despatch packs on trays. Five bricks are being lifted.**

A number of visible wrist / hand abnormalities were noticed during visits. It is likely that detailed clinical examinations would have found more abnormalities, particularly the less immediately obvious ones.

### *3.3.9. Use of painkillers*

It became clear in discussions with packers that some of them make regular use of over-the-counter painkillers such as aspirin and paracetemol in order to be able to continue working. No attempt was made to gauge the frequency of such use.

## 3.4. Accident reports

A wide range of accident reports were noted at the different plants. The general consensus is that wrist and backs are the most commonly affected parts of the body due to packing. These can include back strains, pulled muscles, sprains and tenosynovitis. There were also injuries due to bricks being dropped or falling on parts of the body such as fingers or feet (wearing of gloves and safety footwear is universal), tripping over waste bricks on the floor and packers falling through unstable kiln packs.

## 3.5. Survey of musculoskeletal 'trouble' using the HSE version of the Nordic Musculoskeletal Questionnaire (NMQ)

### *3.5.1. Response rates*

A total of 139 questionnaires (Appendix 2) were completed at the 12 plants. 67 questionnaires were completed at plants employing a total of 86 workers on hand packing. 72 questionnaires were completed at plants employing a total of 94 packers on monorails. Numbers of packers ranged between 4 and 32 at hand packing sites and 6 and 44 on monorails.

At a plant with two shifts which was one of the first plants visited, only one shift was available at the time of the visit. Subsequent visits to plants which operated two shift systems were organised so that both shifts were surveyed, if necessary by returning the following day. In two plants, an individual who had started working as a packer within the previous week was excluded as being too inexperienced. At three plants, a number of workers declined to fill in the questionnaire. At one of these plants, which had both monorail and hand packing, 11 workers employed on hand packing were not surveyed. At one plant a number of workers were not available due to being required for other duties in another part of the plant. At the remaining plants where 100% response rates were not obtained a number of packers were either sick or otherwise unavailable. Because of these problems, the overall response rate of 77% was slightly below the 80% minimum recommended by Dickinson *et al.* (1992). If, however, the 11 unavailable workers at two of the plants are excluded, the overall response rate rises to 82%.

### *3.5.2. Anthropometric data*

Basic anthropometric and personal data are reported in Table 14. Reference should be made to Appendix 1 for the meanings of the statistical terms used here and later in this report and to

Appendix 2 for the actual questionnaire. It must also be born in mind that these data are based on self-reports on the NMQ and therefore are prone to recall error and bias. Thus it is known that self-reports tend to overestimate height and underestimate weight.

**Table 14: Anthropometric and work duration data**

| | UK population, Mean (SD) Pheasant, 1986) | All packers (n=139) Mean (SD) | Hand packing (n=67) Mean (SD) | Monorail packing (n=72) Mean (SD) | Difference in means | t value (unpaired t-test) | Significance |
|---|---|---|---|---|---|---|---|
| **Age (years)** | - | 36.9 (8.9) | 37.5 (9.3) | 36.4 (8.5) | 1.1 | 0.74 | NS |
| **Weight (kilograms)** | 74.5 (11.7) | 77.9 (10.4) | 77.4 (9.4) | 78.4 (11.1) | -1.0 | 0.57 | NS |
| **Height (metres)** | 1.74 (0.07) | 1.77 (0.07) | 1.78 (0.06) | 1.77 (0.07) | 0.010 | 1.16 | NS |
| **Body mass index ($kg/m^2$)** | - | 24.8 (2.9) | 24.5 (2.9) | 25.1 (2.9) | -0.6 | 1.27 | NS |
| **Experience (years)** | - | 8.7 (8.3) | 10.2 (9.8) | 7.3 (6.2) | 2.9 | 2.04 | $P < 0.05$ |
| **Working week (hours)** | - | 38 (6.9) | 36.8 (8.1) | 39.1 (5.6) | -2.3 | 1.33 | NS |

The only statistically significant difference in these data between the two groups of packers was that the hand packers had on average almost three years more experience in the job than packers on monorails. The mean age was in the mid-thirties and the mean experience in the job was approximately nine years. Ages ranged between 59.1 years and 20.3 years. Experience ranged between 38 years and 1 month. As mentioned previously, workers with less experience were not asked to complete the questionnaire.

- Overall, the packers studied were significantly heavier than the UK adult male population by 3.4 kg (7.5 lb). (Standard normal deviate = 3.33, $P < 0.001$). Body weights ranged between 112 kg and 55 kg.

- Overall, the packers studied were also significantly taller than the UK male population by 32 mm (1.25”) (standard normal deviate = 5.39, $P < 0.001$). Statures ranged between 1.93 m and 1.63 m.

Body Mass Index (BMI) is a measure of obesity defined as weight in kilograms divided by height in metres squared. Somewhat arbitrary boundaries have been defined as follows (Knight, 1984):

- < 20 Underweight;
- 20-25 Normal;
- 25-30 Overweight;
- > 30 Obese.

The mean value of 24.8 obtained was just inside the normal range, suggesting that brick packers are towards the heavy-for-height end of the population with a proportion being overweight. The maximum BMI obtained was 34.9 and the minimum 18.5.

- It therefore appears that the packers who succeed in staying in the job are generally taller and heavier than the UK average.

It is likely that the demands of the job affect body weight and hence obesity, particularly in terms of the energy expenditure required and the need, particularly when packing outdoors, to adapt to ambient temperatures which can vary significantly during the day and through the year. Comments made during visits included one packer reporting that he had lost a significant amount of weight as a result of starting packing, and a comment from a plant manager that the leaner workers tended to be better adapted than fatter ones.

Self-reported work hours averaged 38.0 (SD 6.9). There was a wide spread due to factors such as job and finish causing short weeks in some plants, and shift systems and overtime (not necessarily on packing) causing long weeks in other plants. Figures reported ranged between 60 hours per week and 25 hours per week.

Table 15 shows the distribution of handedness among the respondents to the questionnaire. According to Pheasant (1986) approximately 10% of the population are left handed, but he does not give a figure for ambidextrousness.

- It therefore appears that this sample is reasonably representative of the UK population in its handedness.

- There was no difference in handedness proportions between the two packing methods.

**Table 15: Handedness of respondents**

| | Hand packing | Monorail packing | Totals |
|---|---|---|---|
| **Right handed** | 54 (39%) | 57 (41%) | 111 (80%) |
| **Left handed** | 8 (6%) | 9 (6%) | 17 (12%) |
| **Ambidextrous** | 5 (4%) | 6 (4%) | 11 (8%) |
| **Totals** | 67 (48%) | 72 (52%) | 139 (100%) |

### *3.5.3. Musculoskeletal trouble in hand packing and monorail packing*

For 15 / 27 questions regarding musculoskeletal trouble 67 were answered by the 67 respondents at hand packing plants. A single response was missing for each of the remaining 12 questions, 11 from one individual. For monorails 24 /27 questions were completed by all 72 respondents. The remaining three questions were each missing a single response. Frequencies of reports on the questionnaire of musculoskeletal trouble (‘ache, pain, discomfort, numbness’) in the previous year (‘annual prevalence’), and previous seven days (‘weekly prevalence’), and frequencies of effects of the trouble in the past year on normal activities (‘annual disability’), were calculated for the nine different body regions using the actual number of responses for each question. For the regions (shoulders, elbows and wrists / hands) where subjects had been asked to report for left and right sides of the body separately, a positive report was taken as one from either or both sides. This was done to allow comparison with existing data sets.

Comparisons were drawn between hand packers and monorail packers using the $\chi^2$ test to compare frequencies. These comparisons are made in Tables 16, 17 and 18 for annual prevalence, weekly prevalence and annual disability respectively. Statistical terms are explained in Appendix 1.

## Table 16: Annual prevalence of musculoskeletal trouble among hand packers and monorail packers

| | Hand packing | | Monorail | | % | $\chi^2$ | Significance |
|---|---|---|---|---|---|---|---|
| | **Freq** | **% Freq** | **Freq** | **% Freq** | **Difference** | | |
| **Neck** | 23/67 | 34% | 28/71 | 39% | -5% | 0.39 | NS |
| **Shoulders** | 33/67 | 49% | 34/71 | 48% | 1% | 0.03 | NS |
| **Elbows** | 31/67 | 46% | 24/72 | 33% | 13% | 2.43 | NS |
| **Wrists / hands** | 52/67 | 78% | 45/72 | 63% | 15% | 3.76 | NS |
| **Upper back** | 26/66 | 39% | 18/72 | 25% | 14% | 3.28 | NS |
| **Lower back** | 58/67 | 87% | 52/72 | 72% | 14% | 4.33 | P < 0.05 |
| **Hips/thighs/buttocks** | 31/67 | 46% | 31/72 | 43% | 3% | 0.15 | NS |
| **Knees** | 22/67 | 33% | 22/72 | 31% | 2% | 0.08 | NS |
| **Ankles/feet** | 13/67 | 19% | 15/72 | 21% | -1% | 0.04 | NS |

## Table 17: Weekly prevalence of musculoskeletal trouble among hand packers and monorail packers

| | Hand packing | | Monorail | | % | $\chi^2$ | Significance |
|---|---|---|---|---|---|---|---|
| | **Freq** | **% Freq** | **Freq** | **% Freq** | **Difference** | | |
| **Neck** | 9/66 | 14% | 9/72 | 13% | 1% | 0.04 | NS |
| **Shoulders** | 11/66 | 17% | 18/71 | 25% | -9% | 1.55 | NS |
| **Elbows** | 17/66 | 26% | 12/72 | 17% | 9% | 1.71 | NS |
| **Wrists / hands** | 32/66 | 48% | 19/72 | 26% | 22% | 7.22 | P < 0.01 |
| **Upper back** | 21/66 | 32% | 11/72 | 15% | 17% | 5.29 | P < 0.05 |
| **Lower back** | 42/66 | 64% | 34/72 | 47% | 16% | 3.75 | NS |
| **Hips/thighs/buttocks** | 19/66 | 29% | 21/72 | 29% | -0% | 0.00 | NS |
| **Knees** | 9/66 | 14% | 9/72 | 13% | 1% | 0.04 | NS |
| **Ankles/feet** | 7/66 | 11% | 9/72 | 13% | -2% | 0.12 | NS |

## Table 18: Annual disability due to musculoskeletal trouble among hand packers and monorail packers

| | Hand packing | | Monorail | | % | $\chi^2$ | Significance |
|---|---|---|---|---|---|---|---|
| | **Freq** | **% Freq** | **Freq** | **% Freq** | **Difference** | | |
| **Neck** | 7/67 | 10% | 7/72 | 10% | 1% | 0.02 | NS |
| **Shoulders** | 11/66 | 17% | 12/72 | 17% | 0% | 0.00 | NS |
| **Elbows** | 11/67 | 16% | 6/72 | 8% | 8% | 2.11 | NS |
| **Wrists / hands** | 19/67 | 28% | 11/72 | 15% | 13% | 3.51 | NS |
| **Upper back** | 10/66 | 15% | 8/72 | 11% | 4% | 0.50 | NS |
| **Lower back** | 26/67 | 39% | 26/72 | 36% | 3% | 0.11 | NS |
| **Hips/thighs/buttocks** | 13/67 | 19% | 18/72 | 25% | -6% | 0.63 | NS |
| **Knees** | 6/67 | 9% | 10/72 | 14% | -5% | 0.83 | NS |
| **Ankles/feet** | 7/67 | 10% | 7/72 | 10% | 1% | 0.02 | NS |

- As can be seen from these tables, the only statistically significant differences between the two packing methods occur in the lower back for annual prevalence and in the wrists / hands and upper back for weekly prevalence.

- In each of these three body regions, higher prevalences were reported by workers engaged in hand packing than in monorail packing, meaning that hand packing was causing significantly more musculoskeletal trouble in these three regions than monorail packing did.

- More hand packers than monorail packers reported problems in the previous year in the lower back (87% and 72%, $\chi^2 = 4.33$, $P < 0.05$).

- In the wrists / hands nearly twice the proportion of hand packers reported problems in the previous week than did monorail packers (48% and 26%, $\chi^2 = 7.22$, $P < 0.01$).

- More than twice the number of hand packers reported trouble in the previous week in the upper back than did monorail packers (32% and 15%, $\chi^2 = 5.29$, $P < 0.05$).

### *3.5.4. Comparison of musculoskeletal disorders in brick packing and other industries*

Comparisons were also drawn with the 1985 Nordic Reference Data set (Foundation for Occupational and Environmental Medical Research and Development, Orebro, 1985), with data collected by EMAS from bricklayers (PB Francis, personal communication, 1999) and with the suggestions of Dickinson (1998), based on a range of HSE studies using the NMQ, of what should be seen as a 'high' annual prevalence for each body region. These comparisons are made in Table 19 for annual prevalence, Table 20 for weekly prevalence, and Table 21 for annual disability. Figures 6, 7 and 8 compare the frequencies of report for brick packers with bricklayers and with the 1985 Nordic Reference Data.. Figure 6 also includes the 'High' Action Levels suggested by Dickinson (1998).

**Table 19: Annual prevalence of musculoskeletal trouble in brick packers, bricklayers, Nordic reference data, and the suggested 'high' action level based on HSE studies**

| | Hand packing (n=66-67) | Monorail (n=71-72) | Bricklayers (n=127) | Nordic 1985 reference (n=7569) | 'High' action level (Dickinson, 1998) |
|---|---|---|---|---|---|
| **Neck** | 34% | 39% | 32% | 24% | 30% |
| **Shoulders** | 49% | 48% | 36% | 24% | 26% |
| **Elbows** | 46% | 33% | 32% | 10% | 9% |
| **Wrists / hands** | 78% | 63% | 49% | 13% | 25% |
| **Upper back** | 39% | 25% | 14% | 10% | 12% |
| **Lower back** | 87% | 72% | 61% | 41% | 44% |
| **Hips / thighs / buttocks** | 46% | 43% | 13% | 11% | 12% |
| **Knees** | 33% | 31% | 28% | 25% | 27% |
| **Ankles / feet** | 19% | 21% | 17% | 13% | 14% |

**Table 20: Weekly prevalence of musculoskeletal trouble in brick packers, bricklayers, and Nordic reference data**

| | Hand packing (n=66) | Monorail (n=71-72) | Bricklayers (n=127) | Nordic 1985 reference (n=7569) |
|---|---|---|---|---|
| **Neck** | 14% | 13% | 8% | 11% |
| **Shoulders** | 17% | 25% | 6% | 11% |
| **Elbows** | 26% | 17% | 9% | 4% |
| **Wrists / hands** | 48% | 26% | 13% | 6% |
| **Upper back** | 32% | 15% | 5% | 4% |
| **Lower back** | 64% | 47% | 26% | 15% |
| **Hips / thighs / buttocks** | 29% | 29% | 5% | 5% |
| **Knees** | 14% | 13% | 6% | 10% |
| **Ankles / feet** | 11% | 13% | 4% | 6% |

**Table 21: Annual disability due to musculoskeletal trouble in brick packers, bricklayers, and Nordic reference data**

| | Hand packing (n=67) | Monorail (n=71-72) | Bricklayers (n=127) | Nordic 1985 reference (n=7569) |
|---|---|---|---|---|
| **Neck** | 10% | 10% | 2% | 5% |
| **Shoulders** | 17% | 17% | 2% | 4% |
| **Elbows** | 16% | 8% | 7% | 2% |
| **Wrists/ hands** | 28% | 15% | 6% | 2% |
| **Upper back** | 15% | 11% | 3% | 2% |
| **Lower back** | 39% | 36% | 15% | 13% |
| **Hips / thighs / buttocks** | 19% | 25% | 2% | 3% |
| **Knees** | 9% | 14% | 4% | 4% |
| **Ankles / feet** | 10% | 10% | 2% | 3% |

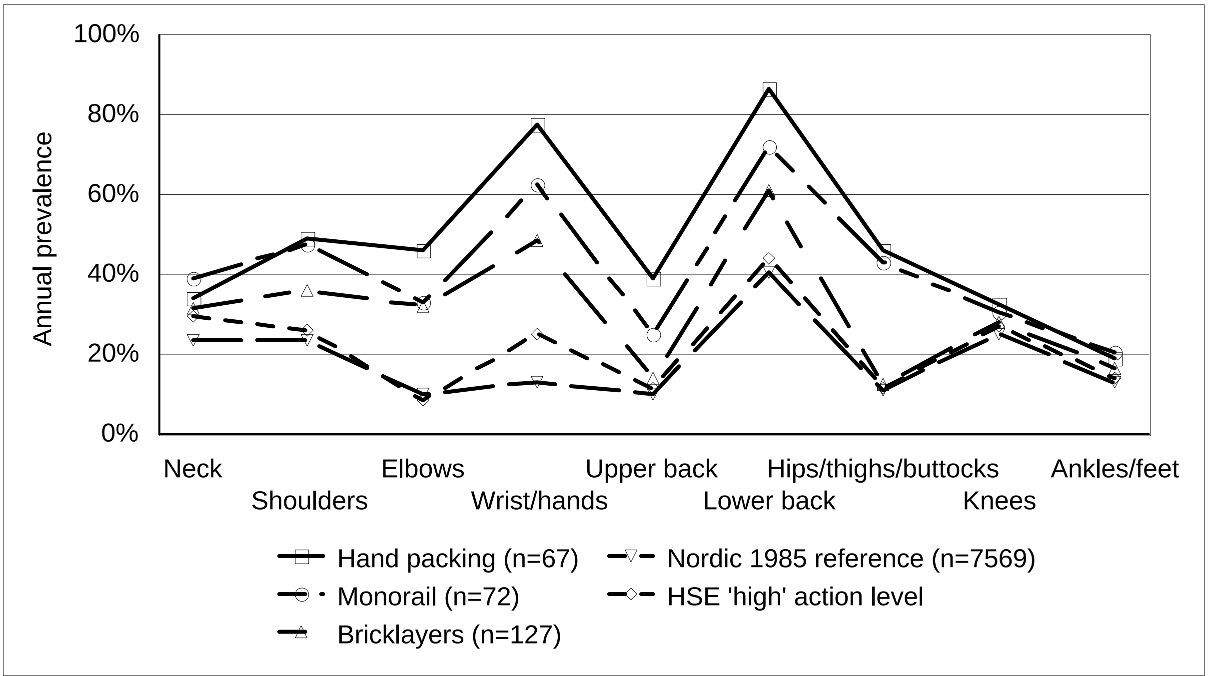


**Figure 6: Comparison of annual prevalence of musculoskeletal trouble among brick packers, bricklayers, Nordic reference data, and HSE reference data**

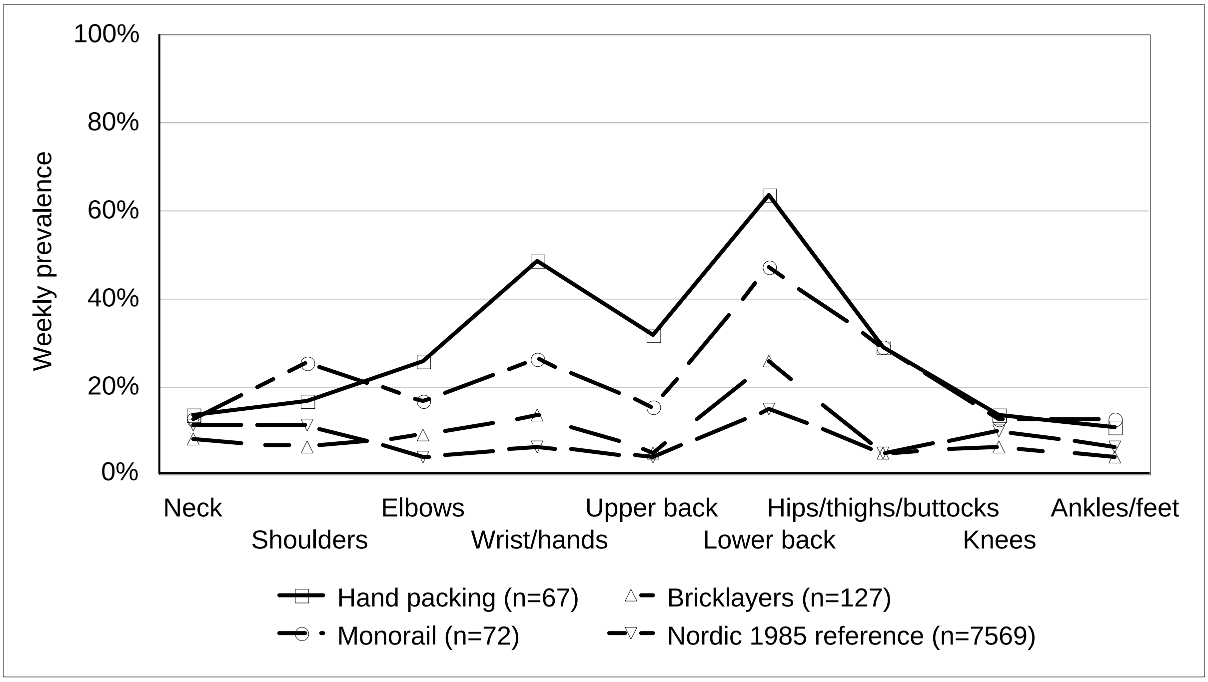


**Figure 7: Comparison of weekly prevalence of musculoskeletal trouble among brick packers, bricklayers and Nordic reference data**

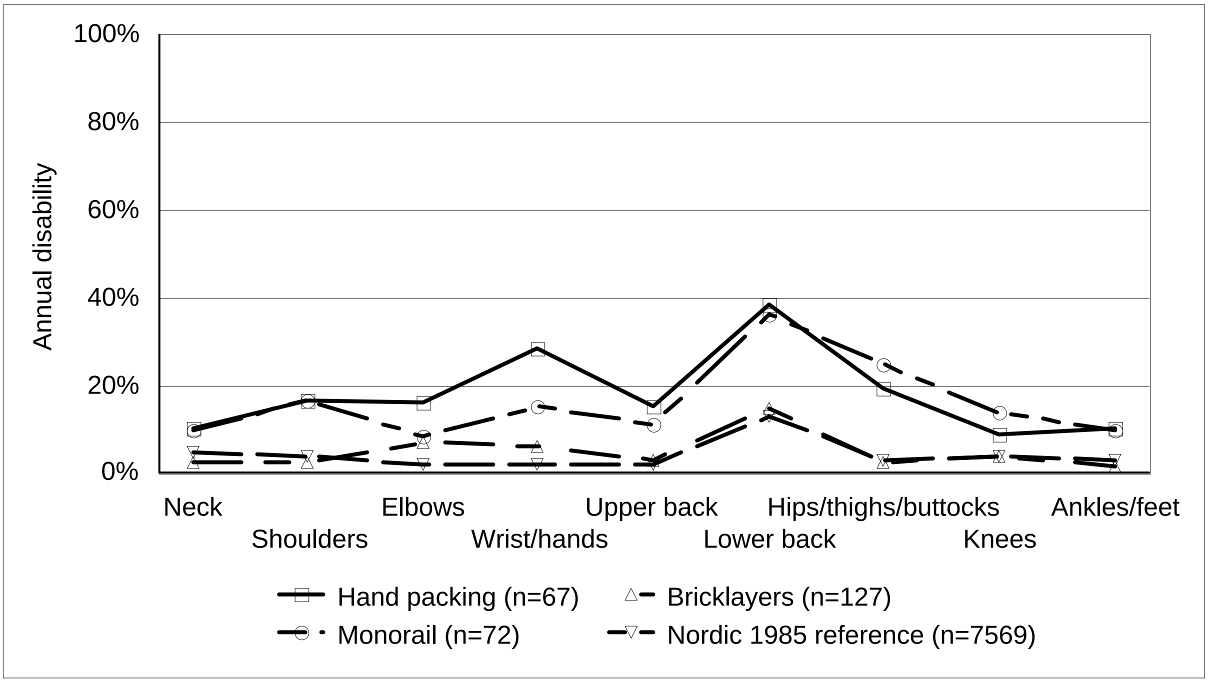


**Figure 8: Comparison of annual disability due to musculoskeletal trouble among brick packers, bricklayers and Nordic reference data**

As can be seen from these results, the absolute levels of musculoskeletal trouble reported by brick packers are very high and very much higher than both the Nordic reference data and the ‘high’ action level suggested by Dickinson (1998) on the basis of HSE studies. The two highest rates of reporting are consistently for the wrists / hands and the lower back. For hand packing the weekly prevalences were 48% and 64% respectively. For monorails the weekly prevalences were 26% and 47% respectively (Table 20).

The relative risks of musculoskeletal trouble for brick packing were calculated using the 1985 Nordic reference data to indicate how much more likely brick packers were to suffer musculo-skeletal trouble than a large population of workers. The relative risks range between 120% and 600% for annual prevalence, 110% and 800% for weekly prevalence, and 190% and 1420% for annual disability. The weekly prevalence relative risks for hand packing and monorails are given in Table 22 for the parts of the body where the risks were much greater.

**Table 22: Relative risks of musculoskeletal trouble (weekly prevalence) for brick packing compared to the 1985 Nordic reference data**

| | Elbows | Wrists / hands | Upper back | Lower back | Hips / thighs / buttocks |
|---|---|---|---|---|---|
| Hand packing | 640% | 600% | 800% | 210% | 580% |
| Monorail packing | 420% | 480% | 380% | 180% | 580% |

The relative risks for brick packing and the annual prevalence 'high' action levels suggested by Dickinson (1998) range between 110% and 510%. For hand packing and monorails these relative risks are given in Table 23 for the five areas of the body where the risks were greatest.

**Table 23: Relative risks of musculoskeletal trouble (annual prevalence) for brick packing and the HSE 'high' action level**

| | Elbows | Wrists / hands | Upper back | Lower back | Hips / thighs / buttocks |
|---|---|---|---|---|---|
| Hand packing | 510% | 310% | 330% | 200% | 390% |
| Monorail packing | 370% | 250% | 210% | 160% | 360% |

The weekly prevalences of musculoskeletal trouble in bricklayers (Table 20 and Figure 7) show that their levels are high but not as high as for packers, and the affected parts of the body are different. Thus, 13% of the bricklayers reported wrists / hands problems in the previous seven days but 48% of hand packers and 26% of monorail packers did. The prevalences in the lower back were 26% for bricklayers and 64% and 47% for hand and monorail packers. Bricklayers were not greatly different to the Nordic reference group in their other body regions.

It is therefore clear that:

- Very high levels of musculoskeletal trouble have been found among brick packers, particularly in the wrists / hands and the lower back;
- These levels are far in excess of average levels in general working populations in both Scandinavia and the UK.

- The levels of problems in the elbows, upper back, and hips / thighs / buttocks, are much higher than the levels in the general Scandinavian and UK working populations.

- These levels are very high when compared to the related job of bricklaying.

Therefore action is necessary to reduce the prevalence of these complaints.

### *3.5.5. Differentiation of bilateral trouble in the shoulders, elbows and wrists / hands from unilateral trouble*

The frequencies of reports of trouble and disability reported above group reports from the two shoulders, the two elbows and the two wrists. Therefore to allow the occurrence of bilateral trouble, e.g., in both elbows, to be seen as more serious than unilateral trouble, e.g., in only one elbow, frequencies of problems in both joints, the right joint, the left joint and neither joint were calculated for weekly trouble for the three regions. The results are given as contingency tables in Tables 24 to 26.

**Table 24: Weekly prevalence of musculoskeletal trouble in the left and right shoulders of brick packers**

| | Trouble in left shoulder | Left shoulder trouble free | Totals |
|---|---|---|---|
| **Trouble in right shoulder** | 16 (12%) | 6 (4%) | 22 (16%) |
| **Right shoulder trouble free** | 7 (5%) | 108 (79%) | 115 (84%) |
| **Totals** | 23 (17%) | 114 (83%) | 137 (100%) |

**Table 25: Weekly prevalence of musculoskeletal trouble in the left and right elbows of brick packers**

| | Trouble in left elbow | Left elbow trouble free | Totals |
|---|---|---|---|
| **Trouble in right elbow** | 12 (9%) | 13 (10%) | 25 (18%) |
| **Right elbow trouble free** | 2 (1%) | 109 (80%) | 111 (82%) |
| **Totals** | 14 (10%) | 122 (90%) | 136 (100%) |

**Table 26: Weekly prevalence of musculoskeletal trouble in the left and right wrists / hands of brick packers**

| | Trouble in left wrist / hand | Left wrist / hand trouble free | Totals |
|---|---|---|---|
| **Trouble in right wrist / hand** | 29 (21%) | 18 (13%) | 47 (34%) |
| **Right wrist / hand trouble free** | 4 (3%) | 87 (63%) | 91 (66%) |
| **Totals** | 33 (24%) | 105 (76%) | 138 (100%) |

- In each body region, of the subjects who reported problems, about half reported them as occurring on both sides of the body and about half reported them as occurring on only one side (12% both shoulders, 9% one shoulder, total 21%; 9% both elbows, 11% one elbow, total 20%; 21% both wrists / hands, 16% one wrist / hand, total 37%).

- The prevalence in the right elbow (18%) was greater than in the left elbow (10%).

- The prevalence in the right wrist / hand (34%) was greater than in the left wrist / hand (24%).

- There was no difference between the prevalences in the two shoulders.

- This suggests that workers are loading the right arm more than the left arm when handling bricks and may be related to handedness.

#### *3.5.6. Calculation of severity scores for musculoskeletal trouble reports*

When an individual is asked a series of related questions, in this case the same three questions about nine different parts of the body, there is a possibility that the process of answering the earlier questions will influence the answers given to the later questions. In other words, it is possible that the answers given about the knees or ankles/feet may be influenced by answers given for the upper or lower back. Therefore, partly to counteract this problem, and partly to gain an overall impression of the amount of trouble / disability being reported across the whole body, severity scores were calculated. Severity scores are methods of assessing the overall severity of reported problems and are widely used for describing the effects of traumatic accidents (e.g., Baker *et al*., 1974). They have also been used for describing the severity of upper limb symptoms in keyboard use (Fuerstein *et al*., 1997) and in carpal tunnel syndrome cases (Levine *et al*., 1993).

It appears that no attempt has been made previously to calculate any kind of severity score for the NMQ. Therefore the following three principles were adopted:

1. Separate severity scores should be calculated for annual prevalence, weekly prevalence and annual disability.

2. The severity score should reflect the number of body regions for which trouble or disability were reported.

3. Left and right shoulders, elbows and wrists / hands should contribute separately to the score.

Therefore the severity score was defined as the total number of body regions in which trouble or disability was reported, with left and right shoulders, elbows and wrists / hands being counted separately for annual and weekly prevalences. Thus the annual and weekly prevalence severity scores can range between 0 and 12 and the annual disability severity score can range between 0 and 9. (The NMQ does not ask respondents for separate reports of disability between the left and right sides for these three regions.)

Table 27 shows the severity scores calculated on this basis.

**Table 27: Comparison of severity scores for hand packing and monorails**

| | All packers (n=139) Mean (SD) | Hand packing (n=67) Mean (SD) | Monorail packing (n=72) Mean (SD) | Difference in means | t value (unpaired t-test) | Significance |
|---|---|---|---|---|---|---|
| **Annual prevalence severity score** | 4.91 (3.16) | 5.39 (3.24) | 4.46 (2.98) | 0.93 | 1.76 | NS |
| **Weekly prevalence severity score** | 2.56 (2.86) | 2.87 (3.05) | 2.28 (2.47) | 0.59 | 1.25 | NS |
| **Annual disability severity score** | 1.53 (2.18) | 1.61 (2.06) | 1.46 (2.17) | 0.15 | 0.43 | NS |

- This shows that the differences in overall severity between hand packing and monorail packing were not statistically significant. In other words, averaged over the whole body, a significant difference in severity of musculoskeletal problems could not be shown between the two methods of packing. This is despite the significant differences shown in some body regions, particularly the lower back and the wrists / hands and suggests that the averaging process tended to mask the localised problems.

### *3.5.7. Comparison of musculoskeletal trouble for different MBLs*

Because of the difficulty of finding plants with an MBL of 2 it had proved impossible to carry out the original plan of a two-way analysis of MBL × packing method. However, the available data were examined in an attempt to identify the effects of different MBLs. This was done using the $\chi^2$ test to examine the proportions of reports of trouble at different MBLs, by comparing groups with MBLs of 2, 4 , 5 and no limit. The $\chi^2$ test is often considered inappropriate if expected frequencies fall below 5. However, according to Keren and Lewis (1993), in a 2 × n contingency table the $\chi^2$ test is appropriate down to expected frequencies of 1.0. Therefore, despite the small numbers with an MBL of 2, which were always likely to lead to small expected frequencies, the $\chi^2$ test was used.

The results are shown in Tables 28, 29 and 30 for annual trouble, weekly trouble and annual disability respectively.

Table 28 shows that, related to MBL, there were significant differences in frequency of annual trouble in the shoulders and hips / thighs / buttocks. However, there was no consistent pattern between the groups in these two areas, with lower rates in the shoulders for MBLs of 2 and 5 than for 4 and no limit. For the hips / thighs / buttocks there was a lower prevalence for an MBL of 4.

## Table 28: Annual trouble prevalence rates for different Maximum Brick Lifts

| | Neck | Shoulders | Elbows | Wrists / hands | Upper back | Lower back | Hips / thighs / buttocks | Knees | Ankles / feet |
|---|---|---|---|---|---|---|---|---|---|
| **MBL = 2 (N=12)** | 8% | 17% | 50% | 0% | 42% | 92% | 50% | 25% | 17% |
| **MBL = 4 (N=35)** | 37% | 49% | 26% | 63% | 20% | 69% | 23% | 29% | 23% |
| **MBL = 5 (N=14)** | 36% | 21% | 36% | 79% | 21% | 71% | 43% | 29% | 7% |
| **No MBL (N=76-78)** | 42% | 58% | 45% | 68% | 38% | 83% | 54% | 35% | 22% |
| $\chi^2$ | 4.93 | 12.02 | 4.36 | 4.16 | 4.69 | 4.84 | 9.55 | 0.78 | 1.85 |
| **Significance (3 df)** | NS | $P < 0.01$ | NS | NS | NS | NS | $P < 0.05$ | NS | NS |

## Table 29: Weekly trouble prevalence rates for different Maximum Brick Lifts

| | Neck | Shoulders | Elbows | Wrists / hands | Upper back | Lower back | Hips / thighs / buttocks | Knees | Ankles / feet |
|---|---|---|---|---|---|---|---|---|---|
| **MBL = 2 (N=12)** | 0% | 0% | 33% | 58% | 33% | 92% | 25% | 8% | 8% |
| **MBL = 4 (N=35)** | 6% | 20% | 6% | 20% | 17% | 69% | 9% | 11% | 17% |
| **MBL = 5 (N=14)** | 21% | 21% | 14% | 29% | 14% | 71% | 29% | 7% | 0% |
| **No MBL (N=76-78)** | 16% | 25% | 27% | 43% | 26% | 83% | 39% | 16% | 12% |
| $\chi^2$ | 3.20 | 3.92 | 8.23 | 8.25 | 2.37 | 4.84 | 10.90 | 1.18 | 3.01 |
| **Significance (3 df)** | NS | NS | $P < 0.05$ | $P < 0.05$ | NS | NS | $P < 0.05$ | NS | NS |

## Table 30: Annual disability prevalence rates for different Maximum Brick Lifts

| | Neck | Shoulders | Elbows | Wrists / hands | Upper back | Lower back | Hips / thighs / buttocks | Knees | Ankles / feet |
|---|---|---|---|---|---|---|---|---|---|
| **MBL = 2 (N=12)** | 8% | 0% | 0% | 25% | 17% | 0% | 8% | 8% | 8% |
| **MBL = 4 (N=35)** | 9% | 3% | 0% | 29% | 6% | 34% | 14% | 14% | 9% |
| **MBL = 5 (N=14)** | 14% | 7% | 14% | 21% | 7% | 29% | 14% | 7% | 7% |
| **No MBL (N=76-78)** | 10% | 27% | 17% | 18% | 17% | 38% | 29% | 12% | 12% |
| $\chi^2$ | 0.40 | 14.36 | 6.58 | 1.70 | 3.23 | 1.46 | 5.49 | 0.65 | 0.44 |
| **Significance (3 df)** | NS | $P < 0.01$ | NS | NS | NS | NS | NS | NS | NS |

## Table 31: Annual prevalence rates for Job and Finish and other hand packing

| | Neck | Shoulders | Elbows | Wrists / hands | Upper back | Lower back | Hips / thighs / buttocks | Knees | Ankles / feet |
|---|---|---|---|---|---|---|---|---|---|
| **Job and Finish (n=22)** | 41% | 41% | 32% | 91% | 36% | 100% | 45% | 36% | 14% |
| **Other hand packing (n=44-45)** | 31% | 53% | 53% | 71% | 41% | 80% | 47% | 31% | 22% |
| $\chi^2$ | 0.63 | 0.91 | 2.75 | 3.33 | 0.13 | 5.08 | 0.01 | 0.18 | 0.70 |
| **Significance (1 df)** | NS | NS | NS | NS | NS | $P < 0.05$ | NS | NS | NS |

## Table 32: Weekly prevalence rates for Job and Finish and other hand packing

| | Neck | Shoulders | Elbows | Wrists / hands | Upper back | Lower back | Hips / thighs / buttocks | Knees | Ankles / feet |
|---|---|---|---|---|---|---|---|---|---|
| **Job and Finish (n=22)** | 18% | 14% | 18% | 45% | 27% | 64% | 14% | 9% | 9% |
| **Other hand packing (n=44-45)** | 11% | 18% | 30% | 50% | 34% | 64% | 36% | 16% | 11% |
| $\chi^2$ | 0.58 | 0.22 | 0.99 | 0.12 | 0.31 | 0.00 | 3.70 | 0.58 | 0.08 |
| **Significance (1 df)** | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## Table 33: Annual disability rates for Job and Finish and other hand packing

| | Neck | Shoulders | Elbows | Wrists / hands | Upper back | Lower back | Hips / thighs / buttocks | Knees | Ankles / feet |
|---|---|---|---|---|---|---|---|---|---|
| **Job and Finish (n=22)** | 9% | 9% | 9% | 50% | 9% | 50% | 9% | 9% | 5% |
| **Other hand packing (n=44-45)** | 11% | 20% | 20% | 18% | 18% | 33% | 24% | 9% | 13% |
| $\chi^2$ | 0.06 | 1.36 | 1.28 | 7.55 | 0.94 | 1.73 | 2.23 | 0.00 | 1.22 |
| **Significance (1 df)** | NS | NS | NS | $P < 0.01$ | NS | NS | NS | NS | NS |

Table 29 shows that there were significant differences in weekly prevalences in the elbows, in the wrists / hands and in the hips / thighs / buttocks. In the elbows and wrists / hands the plants with MBLs of 4 or 5 had lower prevalences than the plants with an MBL of 2 or no MBL. In the hips / thighs / buttocks the same pattern was found as for the annual prevalence, with a lower prevalence for an MBL of 4.

Table 30 shows that the MBL was associated with differences in annual disability prevalence in the shoulders with plants without an MBL having a higher prevalence than the other plants.

- Overall there are few significant differences between the reports on the NMQ for the different MBLs. Of the six there are, four are only significant at the $P < 0.05$ level. This suggests that the associations of different MBLs with reports of musculoskeletal trouble are fairly small.

- The only consistent patterns found were that the significant associations were with the upper limb (shoulders, elbows, wrists / hands) and hips/thighs/buttocks. This is reasonable given that these regions are heavily involved in manual handling.

- It is impossible to draw more definite conclusions on the effect of MBL on musculoskeletal trouble given the lack of pattern in the findings and the relatively small associations and the lack of plants with MBLs of 2.

### *3.5.8. Effect of Job and Finish on reports of musculoskeletal trouble*

Employment practices such as Job and Finish lead to workers packing at rates exceeding the hourly targets they are set in order to be able to leave early. To test whether this practice affected the level of reports of musculoskeletal trouble NMQ data from three plants operating in this way was compared with data from the three other plants using hand packing. This was done using data from hand packing plants only as no monorails visited were operating Job and Finish. The results are shown in Tables 31, 32 and 33 for annual prevalence, weekly prevalence and annual disability respectively. These results compare the levels of trouble reported in these two systems. The issue of the absolute level of the reports was dealt with in the comparison with the data for bricklayers and the Nordic reference data. (Section 3.5.4)

Only two significant differences were found, which were both related to the two areas of the body with the highest rates of problems, the wrists / hands, and the lower back (Section 3.5.3). The annual prevalence of trouble in the lower back was significantly greater in Job and Finish than in other hand packing (100% vs 80%, $\chi^2 = 5.08$, $P < 0.05$). In other words, all packers in plants operating Job and Finish reported musculoskeletal trouble in the lower back in the previous year, but only 80% of the packers in hand packing plants not operating Job and Finish reported such trouble.

The other significant finding was that the annual disability rate for the wrists / hands was significantly higher in Job and Finish than in other hand packing (50% vs 18%, $\chi^2 = 7.55$, $P < 0.01$). In other words, 50% of packers working Job and Finish reported having been prevented from carrying out normal activities in the past year due to musculoskeletal trouble in the wrists / hands, but only 18% of packers in non Job and Finish hand packing plants reported such a limitation.

## 3.6. Ratings of Perceived Exertion

The results of the comparison, using Student's t-test, of the ratings of perceived exertion for hand packing and monorail packing are shown in Table 34. (The full RPE scale is in Appendix 2). These ratings were mostly obtained from subjects who had experience of only one type of packing, but a few individuals had experience of both types.

**Table 34: Ratings of Perceived Exertion for hand packing and monorail packing**

| | Hand packing (n=67) Mean (SD) | Monorail packing (n=72) Mean (SD) | Difference in means | t value (unpaired t-test) | Significance |
|---|---|---|---|---|---|
| **RPE** | 17.5 (2.23) | 16.4 (2.44) | 1.12 | 2.82 | $P < 0.01$ |

- Subjects rated both types of packing as very strenuous with both methods having mean ratings in the 'Very Hard' region.
- Hand packing was seen as more strenuous than monorail packing with a mean difference of over one point on the scale, which was statistically significant at the 1% level.
- Subjective comments from individuals who had experience of both packing methods made it clear that they considered hand packing to be harder, largely due to the greater amount of bending required.

## 3.7. Heart rate monitoring

### *3.7.1. Heart rates in hand packing and monorail packing*

Heart rate data comparing hand packing and monorails are presented in Table 35.

- A significant difference of 8.8 bpm ($P < 0.05$) was found in working heart rates between the two types of packing. As a result of this difference significant differences were found in heart rate reserve (HRR) ($P < 0.05$), work pulse ($P < 0.05$) and work pulse as a percentage of HRR ($P < 0.01$).
- Significantly more time was spent working at higher levels of the HRR ($P < 0.01$) by the hand packers than the monorail packers.
- The lack of significant differences in resting heart rate (Rest HR) and maximum heart rate shows that the differences in HRR and work pulse were due to the differences in working heart rate.
- Therefore the workers in the two systems of work were comparable as groups of individuals and the observed differences in the working heart rate were due to the differences between the two methods of packing.

### Table 35: Heart rate data from monorails and hand packing

| | Hand packing (n=22) Mean (SD) | Monorails (n=23) Mean (SD) | Difference in means | t value (unpaired t-test) | Significance |
|---|---|---|---|---|---|
| **Age (years)** | 39.0 (9.8) | 33.3 (8.4) | 5.7 | 24.00 | P < 0.001 |
| **Maximum heart rate (bpm)** | 181.1 (9.8) | 186.7 (8.5) | 5.6 | 2.00 | NS |
| **Working heart rate (bpm)** | 115.3 (13.7) | 106.5 (9.6) | 8.8 | 2.45 | P < 0.05 |
| **Resting heart rate (bpm)** | 78.3 (7.6) | 75.3 (8.1) | 3.0 | 1.25 | NS |
| **HRR (bpm)** | 102.8 (9.7) | 111.3 (11.7) | 8.6 | 2.60 | P < 0.05 |
| **Work pulse (bpm)** | 37.0 (9.5) | 31.2 (7.3) | 5.8 | 2.25 | P < 0.05 |
| **Work pulse as %Rest HR** | 47.3% (11.6%) | 42.1% (12.3%) | 5.2% | 1.43 | NS |
| **Work pulse as %HRR** | 36.3% (9.4%) | 28.1% (5.8%) | 8.2% | 3.44 | P < 0.01 |
| **%time at > 40% HRR** | 14.3% (12.6%) | 4.7% (3.6%) | 9.7% | 3.44 | P < 0.01 |
| **%time at > 50% HRR** | 3.5% (5.1%) | 0.7% (0.8%) | 2.9% | 2.58 | P < 0.05 |

Astrand and Rodahl (1986) give the following classification of severity of work load for prolonged physical work in terms of mean heart rate:

- up to 90 bpm : 'light work';
- from 90 to 110 bpm : 'moderate work';
- from 110 to 130 bpm : 'heavy work';
- from 130 to 150 bpm : 'very heavy work'
- from 150 to 170 bpm : 'extremely heavy work'.

Astrand and Rodahl (1986) do warn that attempts to establish maximum permissible levels for daily energy output may be quite meaningless in view of the great individual differences in physical work capacity and fitness, and that the level of activity in many industrial tasks is actually self-regulatory in that the rate of work and the spacing of rest pauses are set by the individual's level of physical fitness.

- Brick packing is a fairly strenuous task physiologically.
- Hand packing is more strenuous than monorail packing because it causes a higher average working heart rate of almost 9 beats per minute.
- On average, monorail packing falls into the 'moderate work' category and hand packing falls into the 'heavy work' category.
- The present system where generous rest breaks are provided is almost certainly what keeps the task from being physiologically excessive.

The measurements were made between November and January when ambient temperatures were not high; factors such as high summer temperature could increase heart rates, sweat loss and energy expenditure. As an indication of the effects of temperature, it has been shown that working in an ambient temperature of 43.3°C caused heart rate to increase by approximately 20 beats per minute more than when working in an ambient temperature of 25.6°C (Astrand

and Rodahl, 1986). Also, Hafez and Ayoub (1991) found a reduction in manual lifting capability of well-acclimatised subjects when wet bulb globe temperature (WBGT) increased from 27°C to 32°C, with a greater decrease with temperature at faster lifting rates. For infrequent lifts there was no reduction, but at three lifts per minute the reduction was 18% and at six lifts per minute the reduction increased to 21%.

### *3.7.2. Effect of MBL of 2 in hand packing*

The heart rate measures obtained from the data collected at the hand packing plants were split between the data collected at the two plants with MBLs of 2 and the four plants with no MBL or an MBL of 4 in order to see if there were any differences due to the MBL. The results of this are shown in Table 36.

No significant differences were found between these two methods of packing in terms of heart rate measures. However, caution must be exercised in interpreting these results as the sample sizes are small and there are many differences between plants, such as in the packing methods in use.

**Table 36: Comparison of hand packing plants with an MBL of 2 and other MBLs**

| | No MBL or MBL = 4 (n=15) Mean (SD) | MBL = 2 (n=7) Mean (SD) | Difference in means | t value (unpaired t-test) | Significance |
|---|---|---|---|---|---|
| **Maximum heart rate (bpm)** | 183 (9.8) | 177 (8.3) | 6 | 1.34 | NS |
| **Working heart rate (bpm)** | 118.9 (12.6) | 107.7 (13.0) | 11.3 | 1.85 | NS |
| **Resting heart rate (bpm)** | 79.6 (6.7) | 75.6 (8.6) | 4 | 1.14 | NS |
| **HRR (bpm)** | 103.4 (8.8) | 101.4 (11.1) | 2 | 0.43 | NS |
| **Work pulse (bpm)** | 39.3 (9.8) | 32.1 (6.4) | 7.3 | 1.71 | NS |
| **Work pulse as %Rest HR** | 49.5% (12.4%) | 42.5% (7.5%) | 7.1% | 1.34 | NS |
| **Work pulse as %HRR** | 38.0% (9.0%) | 32.5% (9.3%) | 5.6% | 1.28 | NS |
| **Time at > 40% HRR** | 14.6% (11.7%) | 13.7% (14.3%) | 0.9% | 0.15 | NS |
| **Time at > 50% HRR** | 4.1% (5.1%) | 2.2% (4.9%) | 1.9% | 0.79 | NS |

For the working heart rate the difference in means was 11.3 beats per minute with standard deviations of 12.6 and 13 beats per minute giving an effect size of 0.88 standard deviations. For the number of subjects measured this gives a power of only 45%. If the desired number of plants with an MBL of 2 had been available, giving 24 in each group rather than 15 and 7, this effect size would have given a power of 85%.

- It can only be concluded that there are insufficient data to show a difference in heart rate due to an MBL being enforced. The data collected merely suggest that there is no difference.

### *3.7.3. Effect of shift systems on heart rate*

Tables 37 and 38 break down the heart rate related measures by plant within hand packing and monorail packing respectively.

There is very little variation in mean working heart rate between the different monorails (range from 101.6 to 108.9 bpm) but much more variation in hand packing (range from 96.5 to 127.4 bpm). Using the information on shift systems (Table 12) showed that the hand packing plants operating Job and Finish (Plants 4, 5 and 6) and a plant where packers were competing with each other because of the way that bricks were brought to them (Plant 9) had much higher mean working heart rates (116.0-117.4 bpm) than Plant 7 (103.9 bpm) which operated a piece work system with a fixed clocking off-time and Plant 10 (96.5 bpm) which had a fixed target and a fixed clocking-off time.

**Table 37: Means (SD) of heart rate related measures for hand packing plants**

| | P4 | P5 | P6 | P7 | P9 | P10 |
|---|---|---|---|---|---|---|
| **Maximum heart rate (bpm)** | 186.8 (1.5) | 174.0 (7.4) | 186.7 (4.6) | 169.5 (7.5) | 190 (5.5) | 181 (7.8) |
| **Overall heart rate (bpm)** | 108.1 (13.6) | 109.3 (14.0) | 109.9 (15.6) | 97.1 (12.0) | 108 (17.8) | 94.5 (12.6) |
| **Working heart rate (bpm)** | 127.4 (5.8) | 116.0 (10.9) | 125.0 (3.4) | 103.9 (11.9) | 121.0 (8.8) | 96.5 (3.8) |
| **Resting heart rate (bpm)** | 81.9 (2.9) | 78.7 (9.7) | 83.2 (7.1) | 73.5 (5.7) | 80.7 (5.9) | 71.5 (4.3) |
| **HRR (bpm)** | 104.9 (2.8) | 95.3 (9.5) | 103.5 (10.2) | 96.0 (7.5) | 109.3 (7.49) | 109.5 (7.4) |
| **Work pulse (bpm)** | 45.5 (5.0) | 37.4 (1.4) | 41.8 (4.7) | 30.3 (8.3) | 40.3 (11.3) | 25.0 (2.0) |
| **Work pulse / Resting HR** | 0.557 (0.065) | 0.480 (0.039) | 0.510 (0.093) | 0.412 (0.109) | 0.508 (0.155) | 0.351 (0.040) |
| **Work pulse / HRR** | 0.434 (0.044) | 0.397 (0.053) | 0.404 (0.035) | 0.321 (0.099) | 0.368 (0.102) | 0.228 (0.006) |
| **Time at > 40% HRR** | 18.4% (11.7%) | 22.5% (13.2%) | 17.4% (8.0%) | 5.1% (4.9%) | 18.1% (13.4%) | 2.0% (1.6%) |
| **Time at > 50% HRR** | 5.2% (3.7%) | 3.6% (6.1%) | 4.3% (4.7%) | 0.1% (0.1%) | 7.0% (6.5%) | 0.3% (0.3%) |

**Table 38: Means (SD) of heart rate related measures for monorail plants**

| | P1 | P2 | P3 | P8 | P11 | P12 |
|---|---|---|---|---|---|---|
| **Maximum heart rate (bpm)** | 182.7 (2.9) | 188.0 (8.7) | 197.5 (0.5) | 186.0 (3.1) | 179.8 (2.6) | 185.0 (11.5) |
| **Overall heart rate (bpm)** | 100.6 (13.2) | 93.3 (12) | 96.9 (15.3) | 98.7 (14.3) | 93.7 (16.9) | 96.6 (16.4) |
| **Working heart rate (bpm)** | 108.5 (10.2) | 105.9 (4.7) | 108.7 (6) | 106.1 (4.9) | 101.6 (13.4) | 108.9 (12.2) |
| **Resting heart rate (bpm)** | 79.1 (10.6) | 72.4 (3.5) | 75.8 (9) | 75.2 (4) | 74.7 (8.7) | 75.8 (9.1) |
| **HRR (bpm)** | 103.6 (13) | 115.6 (9.3) | 121.7 (9.5) | 110.8 (6.1) | 105.1 (8.2) | 109.2 (12.8) |
| **Work pulse (bpm)** | 29.5 (6.8) | 33.5 (5.4) | 32.9 (3.4) | 30.9 (7) | 26.9 (5.4) | 33.0 (11.1) |
| **Work pulse / Resting HR** | 0.384 (0.124) | 0.466 (0.87) | 0.446 (0.097) | 0.416 (0.111) | 0.358 (0.052) | 0.447 (0.186) |
| **Work pulse / HRR** | 0.287 (0.064) | 0.291 (0.044) | 0.270 (0.011) | 0.278 (0.059) | 0.261 (0.066) | 0.298 (0.074) |
| **Time at > 40% HRR** | 4.8% (5.7%) | 2.6% (2.4%) | 4.7% (2.0%) | 5.7% (3.5%) | 4.6% (3.4%) | 5.6% (3.4%) |
| **Time at > 50% HRR** | 0.2% (0.3%) | 0.3% (0.5%) | 0.7% (0.6%) | 1.1% (0.9%) | 0.3% (0.3%) | 1.2% (0.9%) |

- Plants 4,5,6 and 9 fell into the ‘Heavy Work’ category of Astrand and Rodahl (1986) whereas Plants 7 and 10 fell into the ‘Moderate Work’ category, as did all the monorails.

A two-sample t-test was used to compare mean working heart rates at the three plants operating Job and Finish (Plants 4,5,6) with the three other hand packing plants (Plants 7,9,10). The results in Table 39 show that in plants where Job and Finish was permitted mean working heart rates fell into the 'heavy work' category and were significantly greater by 14.5 beats per minute (P = 0.01) than at the others plants, which fell into the 'moderate work' category.

**Table 39: Effect of Job and Finish on heart rates**

| | Job and Finish (n=11) | Other hand packing plants (n=11) | Difference in means | t value (unpaired t-test) | Significance |
|---|---|---|---|---|---|
| **Working heart rate (bpm)** | 122.6 (9.2) | 108.1 (13.7) | 14.5 | 2.79 | P = 0.01 |

To examine the effect of the length of the working day, all the plants were grouped by shift length (Table 12). The results are presented in Table 40.

**Table 40: Effect of actual shift length on mean heart rate**

| Actual shift length | < 7.5 hours | 7.5 - 9 hours | > 9 hours |
|---|---|---|---|
| Mean working heart rate (bpm) | 122.6 | 104.5 | 109.9 |
| Mean overall heart rate (bpm) | 109.6 | 98.0 | 99.0 |

For plants where the actual shift length was less than 7.5 hours (Plants 4, 5, 6) the mean heart rate was highest. These were the plants operating Job and Finish. When actual shift length was more than 9 hours (Plants 2,7,9,12) the mean working heart rate was 5.4 bpm greater than in plants where the actual shift length was between 7.5 and 9 hours (Plants 1, 3, 8, 10, 11). However, the overall heart rates, which also includes rest breaks, in these two groups of plants had a difference of only one bpm. Therefore the plants with the extended work shifts (9 hours +) did not make greater overall physiological demands than those with 'standard' length days of 7.5 to 9 hours. This will be a function of the way in which the workers spread the work over the day and intersperse their rest breaks.

There is evidence (Mital *et al.*, 1997; Mital, 1983) that workers consider that the maximum weight they can comfortably handle over a work shift decreases if the shift length increases from 8 to 12 hours. This reduction appears to be to maintain constant levels of fatigue and was for a work system with 'normal' rest breaks rather than the more generous ones available in brick packing.

- It is therefore clear that in plants where individuals can work at their own individual pace (i.e., hand packing) and have the incentive of finishing early, the system of work causes individuals to work at much greater rates.

- Provided adequate rest breaks are allowed, it appears that the length of shift being worked does not adversely affect the physiological load.

### *3.7.4. Fatigue trends*

Of the 45 correlations obtained by analysing the relationships between time of day and heart rate using linear regression, only seven were significant at the 5% level. Of the seven significant correlations four were at three plants that operated job and finish and the other three were at a single monorail.

It seems likely that the finding of three significant correlations at a single monorail (Plant 3) is indicative that the work system at that plant was tending to cause fatigue. It is noticeable that these three workers were all aged under 25 years, and therefore had high expected maximum heart rates. Despite the fatigue trend, the working heart rates for these three individuals were relatively low, with two below 105 bpm and one below 115 bpm. The work pulses for these individuals were 34.2, 37.9 and 29.5 bpm. By contrast the mean working heart rate across all plants was 110.8 bpm and the mean work pulse was 34.0 bpm. It therefore appears that the work at this plant was not excessive in terms of overall heart rate but was fatiguing. This may be a function of the packing practices at this plant. Several layers of the kiln pack were set on their beds leading to a tendency for the workers to handle only two bricks at a time and to strip down the pack layer by layer rather than stripping down the front of the pack before stripping the back of the pack. This led to an observable tendency to stoop and reach long horizontal distances which will have loaded the muscles of the back and upper limb more than if the approach of stripping the front of the pack had been used.

When averaged across all subjects, and therefore ranging from the earliest start to the latest finish, there was not a significant fatigue trend. Of the seven significant fatigue effects two were at job and finish plants with very early starts (Plant 4 reported as 05:15 am and Plant 6 05:00 am). The remainder were at two plants with shift start times of 07:00.

- Overall, the workers measured were not suffering excessive levels of fatigue as a result of their work.
- There is no discernible time of day effect on fatigue.

## 3.8. Posture analysis

### *3.8.1. Overall posture codings*

The overall results of the posture codings carried out of videotapes filmed at four plants are shown in Table 41. The meanings of the Action Categories were given in Table 5.

**Table 41: Percentage of postures assigned to the different OWAS Action Categories at the different plants**

| | Packing method | No of observations | Action Category 1 | Action Category 2 | Action Category 3 | Action Category 4 |
|---|---|---|---|---|---|---|
| **Plant 2** | Monorail | 1,215 | 69% | 18% | 4% | 9% |
| **Plant 4** | Hand packing | 250 | 44% | 54% | 2% | 1% |
| **Plant 10** | Hand packing | 1,193 | 40% | 56% | 1% | 2% |
| **Plant 11** | Monorail | 745 | 61% | 37% | 0% | 1% |

In interpreting these results it must be remembered that there are significant uncertainties in the OWAS system. This is due to a number of factors including the lack of validation of the OWAS system, especially in the detailed assignment of postures to Action Categories. Uncertainties also arise due to the nature of the classification system, which only categorises gross postures, and due to the sampling process which only dealt with at most four subjects at each plant, which means that subject idiosyncrasies may have affected the results. Therefore it would be unwise to treat small differences in results as representing important differences, but larger differences (e.g., greater than 10%) can be taken to represent meaningful differences.

- At each of the plants only small percentages of time (at most 13%) were spent in postures linked to the worst two Action Categories (Categories 3 and 4).

- Approximately two-thirds of the monorail postures were classified as belonging to Action Category 1. However, for the hand packing sites under 50% of the postures were classified as Action Category 1, and as a result over 50% were classified as Action Category 2.

- Therefore, in terms of the classification of gross postures which the OWAS system uses, hand packing is posturally worse than monorail packing. The precise reasons for this will be discussed below where the Action Categories are broken down into the individual postures which contribute to them.

### *3.8.2. Breakdown of Action Categories by posture*

The overall figures for Action Categories given in Table 41 are broken down by body part in Table 42 to allow identification of the components of posture which are contributing to the harmful overall postures.

**Table 42: Breakdown, by body part, of time spent in the different Action Categories**

| Body part | Posture | Plant 2 | | Plant 4 | | Plant 10 | | Plant 11 | |
|---|---|---|---|---|---|---|---|---|---|
| | | % time | AC | % time | AC | % time | AC | % time | AC |
| **Back** | **Straight** | 63% | 1 | 32% | 1 | 36% | 1 | 39% | 1 |
| | **Bent** | 10% | 1 | 19% | 1 | 22% | 1 | 5% | 1 |
| | **Twisted** | 7% | 1 | 12% | 1 | 5% | 1 | 23% | 2 |
| | **Bent and Twisted** | 20% | 2 | 36% | 3 | 38% | 3 | 33% | 3 |
| **Arms** | **Both below shoulder** | 90% | 1 | 98% | 1 | 98% | 1 | 95% | 1 |
| | **One below shoulder** | 7% | 1 | 2% | 1 | 2% | 1 | 5% | 1 |
| | **Both above shoulder** | 2% | 1 | 0% | 1 | 0% | 1 | 0% | 1 |
| **Legs** | **Sitting** | 2% | 1 | 0% | 1 | 2% | 1 | 0% | 1 |
| | **Standing on two legs** | 60% | 1 | 84% | 2 | 76% | 1 | 86% | 2 |
| | **Standing on one leg** | 6% | 1 | 2% | 1 | 3% | 1 | 3% | 1 |
| | **Standing on two bent knees** | 12% | 2 | 2% | 1 | 3% | 1 | 1% | 1 |
| | **Standing on one bent knee** | 1% | 1 | 0% | 1 | 0% | 1 | 1% | 1 |
| | **Kneeling** | 0% | 1 | 0% | 1 | 0% | 1 | 0% | 1 |
| | **Walking** | 19% | 1 | 11% | 1 | 15% | 1 | 9% | 1 |
| **Load** | **< 10 kg** | 80% | 1 | 91% | 1 | 99% | 1 | 89% | 1 |
| | **< 20 kg** | 20% | 1 | 9% | 1 | 1% | 1 | 11% | 1 |
| | **> 20 kg** | 0% | 1 | 0% | 1 | 0% | 1 | 0% | 1 |

The only postures classified as harmful by this breakdown relate to the back and the legs. They do not relate to the arms or the load being handled, but it must be remembered that the categorisation of arm postures was merely related to position relative to the shoulders.

- Therefore this categorisation does not say anything about detailed hand / wrist postures which are of importance because they depend on the ways in which bricks are actually handled. On the basis of the NMQ results and anecdotal reports it is clear that wrist postures are important causes of musculoskeletal problems.

- The major problem revealed by this posture analysis is that of bending and twisting of the trunk which reaches Action Category 3 in three plants and Action Category 2 in the other. Twisting by itself also reaches Action Category 2 in one plant.

- Therefore this indicates that remedial steps are necessary to reduce the amount of bending and twisting, which can be done either by reducing the need to bend or the need to twist as reductions in either of these will result in reductions in the combination.

The only other problem revealed was that the amount of ordinary standing on two legs reached Action Category 2 in Plants 4 and 11, and the amount of standing on two legs with bent knees in Plant 2 also reached Action Category 2. This latter finding reflected the observed tendency of workers in this plant to bend their knees more when lifting. It is difficult to suggest methods of reducing the amount of standing in this work, except to recommend more variety such as more walking. However, as these postures are only classified into Action Category 2, remedial action is not an urgent priority.

### *3.8.3. Breakdown of OWAS Action Categories by plant and posture*

Tables 43 to 47 give breakdowns of the frequencies of the different postures observed at the four different plants and across all plants. This is done using the Action Categories and four digit posture codes. Percentages are of the total number of observations at each plant, across all four Action Categories. Posture codes can be decoded using Table 4.

**Table 43: Breakdown of Action Categories by posture at Plant 2**

| Posture | Freq. | % | Posture | Freq. | % | Posture | Freq. | % |
|---|---|---|---|---|---|---|---|---|
| **AC 1** | **840** | **69%** | | | | | | |
| 1121 | 392 | 32% | 1171 | 152 | 13% | 1221 | 59 | 5% |
| 1131 | 50 | 4% | 3121 | 37 | 3% | 1172 | 32 | 3% |
| 1122 | 23 | 2% | 3122 | 22 | 2% | 1271 | 11 | 1% |
| 1321 | 10 | 1% | 1111 | 9 | 1% | 1322 | 7 | 1 |
| Others (13) | 36 | 3% | | | | | | |
| **AC 2** | **215** | **18%** | | | | | | |
| 4121 | 67 | 6% | 2121 | 46 | 4% | 4122 | 39 | 3% |
| 2122 | 15 | 1% | 2111 | 10 | 1% | Others (12) | 38 | 3% |
| **AC 3** | **46** | **4%** | | | | | | |
| 2141 | 17 | 1% | 2142 | 13 | 1% | Others (6) | 16 | 1% |
| **AC 4** | **114** | **9%** | | | | | | |
| 4141 | 65 | 5% | 4142 | 44 | 4% | Others (3) | 5 | 0% |

**Table 44: Breakdown of Action Categories by posture at Plant 4**

| Posture | Freq. | % | Posture | Freq. | % | Posture | Freq. | % |
|---|---|---|---|---|---|---|---|---|
| **AC 1** | **110** | **44%** | | | | | | |
| 1121 | 54 | 22% | 1171 | 23 | 9% | 3121 | 21 | 8% |
| 3122 | 6 | 2% | 3171 | 3 | 1% | 1221 | 2 | 1% |
| 1122 | 1 | 0% | | | | | | |
| **AC 2** | **134** | **54%** | | | | | | |
| 4121 | 73 | 29% | 2121 | 37 | 15% | 4122 | 11 | 4% |
| 2131 | 4 | 2% | 2122 | 3 | 1% | 4131 | 2 | 1% |
| 4221 | 2 | 1% | 2171 | 1 | 0% | 4111 | 1 | 0% |
| **AC 3** | **4** | **2%** | | | | | | |
| 2141 | 3 | 1% | 3142 | 1 | 0% | | | |
| **AC 4** | **2** | **1%** | | | | | | |
| 4141 | 1 | 0% | 4142 | 1 | 0% | | | |

**Table 45: Breakdown of Action Categories by posture at Plant 10**

| Posture | Freq. | % | Posture | Freq. | % | Posture | Freq. | % |
|---|---|---|---|---|---|---|---|---|
| **AC 1** | **479** | **40%** | | | | | | |
| 1121 | 248 | 21% | 1171 | 124 | 10% | 3121 | 46 | 4% |
| 1111 | 21 | 2% | 1131 | 8 | 1% | 1221 | 8 | 1% |
| Others (8) | 24 | 2% | | | | | | |
| **AC 2** | **673** | **56%** | | | | | | |
| 4121 | 392 | 33% | 2121 | 203 | 17% | 2171 | 20 | 2% |
| 4131 | 20 | 2% | 4171 | 13 | 1% | 2131 | 8 | 1% |
| Others (8) | 17 | 1% | | | | | | |
| **AC 3** | **15** | **1%** | | | | | | |
| 2141 | 10 | 1% | Others (4) | 5 | 0% | | | |
| **AC 4** | **26** | **2%** | | | | | | |
| 4141 | 26 | 2% | | | | | | |

**Table 46: Breakdown of Action Categories by postures at Plant 11**

| Posture | Freq. | % | Posture | Freq. | % | Posture | Freq. | % |
|---|---|---|---|---|---|---|---|---|
| **AC 1** | **458** | **61%** | | | | | | |
| 1121 | 208 | 28% | 3121 | 130 | 17% | 1171 | 49 | 7% |
| 3122 | 22 | 3% | 1221 | 21 | 3% | 3171 | 7 | 1% |
| 3221 | 7 | 1% | Others (7) | 14 | 2% | | | |
| **AC 2** | **273** | **37%** | | | | | | |
| 4121 | 174 | 23% | 4122 | 41 | 6% | 2121 | 25 | 3% |
| 4131 | 10 | 1% | Others (9) | 23 | 3% | | | |
| **AC 3** | **3** | **0%** | | | | | | |
| Others (2) | 3 | 0% | | | | | | |
| **AC 4** | **11** | **1%** | | | | | | |
| Others (4) | 11 | 1% | | | | | | |

**Table 47: Breakdown of Action Categories by postures across all four plants**

| Posture | Freq. | % | Posture | Freq. | % | Posture | Freq. | % |
|---|---|---|---|---|---|---|---|---|
| **AC 1** | **1,887** | **55%** | | | | | | |
| 1121 | 902 | 27% | 1171 | 348 | 10% | 3121 | 234 | 7% |
| 1221 | 90 | 3% | 1131 | 62 | 2% | 3122 | 50 | 1% |
| 1172 | 37% | 1% | 1111 | 30 | 1% | 1122 | 24 | 1% |
| 3171 | 19 | 1% | 1271 | 18 | 1% | Others (16) | 73 | 2% |
| **AC 2** | **1,295** | **38%** | | | | | | |
| 4121 | 706 | 21% | 2121 | 311 | 9% | 4122 | 92 | 3% |
| 4131 | 37 | 1% | 2171 | 29 | 1% | 2122 | 25 | 1% |
| 2131 | 22 | 1% | 4171 | 21 | 1% | Others (11) | 52 | 2% |
| **AC 3** | **68** | **2%** | | | | | | |
| 2141 | 30 | 1% | Others (11) | 38 | 1% | | | |
| **AC 4** | **153** | **4%** | | | | | | |
| 4141 | 96 | 3% | 4142 | 45 | 1% | Others (4) | 12 | 0% |

Almost all the Action Category 4 postures were 4141 and 4142, both of which involve bending and twisting with both knees bent. Reducing the need for either bending or twisting would reduce the frequency of these postures. The knee bending appeared to be a preferred posture of some workers, rather than keeping the legs straight when lifting.

The most frequent Action Category 3 posture was 2141 which involves bending the trunk and the knees. Action to reduce bending will decrease the frequency of this posture.

The most frequent Action Category 2 postures were 4121, 2121 and 4122. The first two involve a bent and twisted trunk and a bent trunk respectively. Again, reducing the amount of twisting and bending would reduce the frequency of these postures. The 4122 posture is the same as the 4121 posture, except that the load has increased from less than 10 kg to between 10 and 20 kg. This posture occurred only 3% of the time so decreasing the load would probably be less effective than decreasing the amount of bending and twisting of the trunk.

- Reducing bending would probably be best done by increasing minimum heights of lift.

## 4. DISCUSSION

### 4.1. Packing methods

- Hand packing is worse than monorail packing, as it generally involves more bending and stooping due to the lower heights that the despatch packs are positioned at.

- Packing practices are very largely determined by the layout of the workstation and the layouts of both the kiln packs and the despatch packs because these affect the postures that the packers adopt and therefore the amounts of reaching, stooping and twisting needed.

### 4.2. Likelihood of musculoskeletal disorders in brick packing

- It is clear that manual sorting and packing of bricks as currently carried out is a high risk activity for the development of musculoskeletal disorders.

- It is also clear from the differing rates of such problems in the different factories visited that a number of associated factors can influence their occurrence.

Brick packing should be viewed, therefore, as a borderline activity in that while in some circumstances it may not result in musculoskeletal disorders, if the associated factors are not controlled properly, the balance of risk will become unfavourable and lead to the occurrence of musculoskeletal disorders.

### 4.3. Strenuousness of brick packing

Hand packing was shown to be more strenuous than monorail packing. This appears to be due to practices such as job and finish causing workers to work more quickly. The analysis of the heart rate data revealed that packing falls into the broad categories of ‘moderate work’ on monorails and ‘heavy work’ in hand packing. These categories are defined in terms of men aged 20 - 30. Aerobic capacity gradually declines with age, and the average age of the packers studied was 39.0 for hand packing and 33.3 for monorails. Therefore these descriptions should be regarded as possibly understating the demands of the job.

### 4.4. Effectiveness / impact of limiting the number of bricks lifted at one time

There is a preference among packers to handle larger numbers of bricks per lift and perform fewer lifts rather than handling only a few bricks in each lift. One plant was visited specifically because it had introduced a policy of limiting the number of bricks lifted at any time to three. In practice this was found to be completely ignored by the packers who were observed to lift as many as seven bricks at once.

The number of measurements made at plants with MBLs of 2 were too few for the statistical tests used to have sufficient power to reliably detect differences in heart rate due to imposing an MBL. Therefore, the finding of no significant difference between MBLs of 2 and higher MBLs is not definitive. In other words, if sufficient plants with MBLs of 2 had been found, it might have been shown conclusively that an MBL of 2 forces workers to perform more lifts and therefore increases the heart rate.

The fact that upper limits to the number of bricks handled at once have to be imposed, and workers will ignore them if they can, suggests that workers clearly perceive having to lift fewer bricks and perform more lifts as disadvantageous. The most likely reasons are to do with time required to complete the target number of bricks and energy expenditure. In other words, workers prefer to work in ways which they find least tiring, and will accept the increased stress on the hands and wrists from handling larger loads as this will have a more delayed deleterious effect.

These are not the only issues which will affect the success of any policy of limiting the number of bricks handled at one time. The other issues include the orientation of the bricks in the kiln pack, the weights of individual bricks and the inspection policy in operation. It will also be affected by the design of the despatch pack, particularly the number of bricks across its width and the presence of layers of bricks on their beds.

### 4.5. Importance of kiln pack design

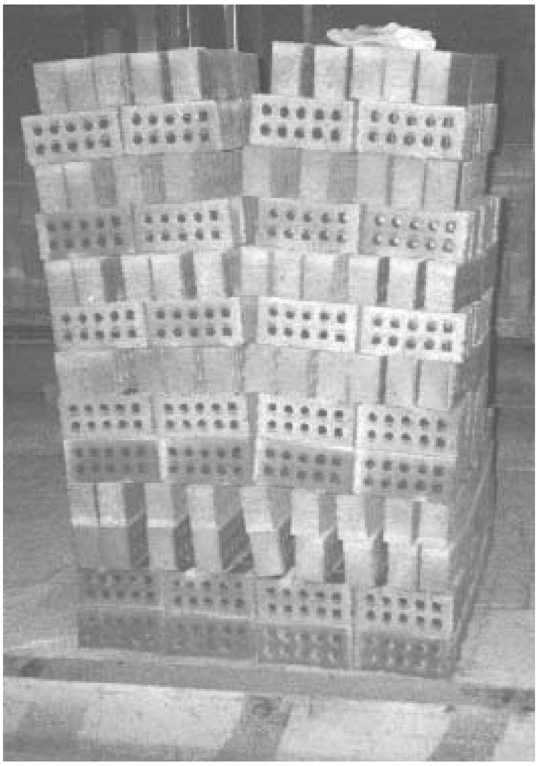

**Figure 9: Problems of kiln pack stability caused by the setting pattern**

Kiln pack design is crucial to all aspects of production. It has implications for setting processes, pack transportation, control of burning, pack stability both outside and inside the kiln, quality of output and the sorting / packing methods used. At one plant changes had been made to the patterns in which bricks were set in an attempt to improve the ease of handling. As a result pack stability had decreased and the risk of collapse increased (Figure 9). Therefore any changes that are made to pack design will need evaluating for their effects throughout the production process.

## 4.6. Importance of psychosocial factors

'Psychosocial' factors relate to the ways in which individuals interact with their social environments, and therefore how their behaviour is influenced. They can lead to acute psychological, behavioural and physiological reactions and ultimately affect health detrimentally (Sauter and Swanson, 1996). Their importance in affecting reports of musculoskeletal disorders and the progression from musculoskeletal trouble to musculoskeletal disability is being increasingly recognised.

Bongers *et al.* (1993) listed five broad categories of psychosocial factors that may be associated with musculoskeletal symptoms. These were:

- Psychosocial factors at work - demands and control
- Psychosocial factors at work - social support
- Individual characteristics
- Stress symptoms
- Physical and behavioural health indicators

It is now recognised that problems such as back pain will affect large proportions of the population at some point in their lives, but a number of factors can transform an acute case of low back pain (LBP) into a chronic case of low back pain disability (LBPD) (Battie, 1992). It is also recognised that the amount of disability associated with back pain has increased over recent decades while the incidence of back pain itself does not appear to have changed dramatically over the same period (Leamon, 1994a,b). The factors which have been linked to disability and reporting rates include definitions of back pain and disability in use, compensation systems, reporting systems, return to work systems, family support for the individual, actual and perceived job requirements, medical interventions, and job satisfaction.

According to Battie (1992) progress in preventing back symptoms and related compensation claims has been limited but evidence suggests that their negative consequences can be limited by a variety of employer-based strategies that focus on minimising disability. She listed the following as common factors in successful disability management

1. 'A Foundation of Employee Advocacy'. What is good for the employee is ultimately good for the employer as well.

2. 'Management Training (changing attitudes towards back pain complaints)'. This is intended to encourage a humane response to injury and illness complaints and to provide an environment more supportive of early return to work. It seeks to put across the message that back symptoms are common and that malingering is rare.

3. 'Improved Quality and Quantify of Communications'. This is intended to convey concern of the well-being of the individual and help identify obstacles in the

workplace or medical or compensation systems that might hamper progress toward recovery.

4. 'Modified Duty Availability'. Temporary modified duty during the recovery period allows the person to continue working and maintain a more normal lifestyle. Early activity plays an important role in recovery and minimising disability. Prolonged inactivity appears to lead to further debilitation and may further complicate symptoms.

5. 'Medical Surveillance'. This involves working with the medical community to accommodate their recommendations and discouraging extremely prolonged activity restrictions.

6. 'Activities are Employer-Based'. This requires employers to assume an active role in minimising disability, with support from upper management, and the adoption of philosophies and practices that support disability prevention, including temporary workplace adaptations if necessary.

Obviously the implementation of such practices within the brick manufacturing industry would need adaptation to local circumstances.

## 4.7. Factors affecting the suitability of the different packing methods

There are a number of factors which have advantages and disadvantages in the different methods of packing bricks. These can conveniently be subdivided into four areas. Factors which relate to the design of the kiln pack and factors related directly to the risks of manual handling are summarised in Table 48. A number of other work-related factors, such as speed of operation, the need for sorting of bricks and blending of kiln packs and the working environment are listed in Table 49, as are financial factors, such as labour and capital costs.

**Table 48: Factors affecting the suitability of automatic dehackers, monorails and hand packing**

| Kiln-related factors | Dehackers | Monorails | Hand packing |
|---|---|---|---|
| **Pack design** | Requires consistent shapes in bricks and kiln packs. | Able to deal with irregular shape kiln packs | Able to deal with irregular shape kiln packs |
| **Pack stability** | Requires stable packs | Requires stable packs | Able to deal with collapsed packs |
| **Manual handling** | | | |
| **Amount** | Reduces manual handling - can require manual handling when waste rates are high or mechanical breakdown occurs. | Requires manual handling | Requires manual handling |
| **Horizontal reach** | | Jigs are only two blades deep which reduces stretching when placing bricks. | Jigs are four/five blades deep causing more reaching. |
| **Stooping** | | Bricks are packed between knee and shoulder height, decreasing stooping. | Causes more stooping, especially when packing from kiln packs on the floor or onto the floor or onto trays on the floor. |
| **Work level** | | 'Moderate' work physiologically | 'Heavy' work physiologically and perceived as harder than monorails by workers |
| **Seconds** | Manual removal of seconds and rejects may be required | Jig pockets or conveyors allow automatic removal of seconds and rejects. Jig pockets fill rapidly with high seconds rates; putting rejects on top of jigs is only acceptable with low reject rates. | Seconds usually packed to separate jig; rejects usually thrown to a skip or conveyor. |

**Table 49: Factors affecting the suitability of automatic dehackers, monorails and hand packing (cont.)**

| Other work-related factors | Dehackers | Monorails | Hand packing |
|---|---|---|---|
| **Strapping** | Automatic strapping | Strapping can be automated | Hand strapping provides a different activity for the workers. |
| **Sorting** | Bad at sorting | Good for sorting | Good for sorting |
| **Blending** | | Allows blending of packs. | |
| **Environment** | | Indoors, so environment can be controlled | Can be outdoors. |
| **Job rotation** | | Job rotation is possible | |
| **Team work** | | Workers have to work as a team. | Workers work as individuals |
| **Speed** | | Monorail has to operate at the pace of the slowest worker. | Self paced |
| **Rest breaks** | | Natural pauses while strapping do not occur. | Strapping provides a break from packing |
| **Worker skill** | Machine operators must be skilled | Machine operator must be skilled; packers must be fit | Packers must be fit |
| **Noise** | Noise levels are increased. | Noise levels are increased. | No machinery generating noise |
| **Breakdown** | Mechanical breakdown possible | Mechanical breakdown possible | No machinery maintenance required |
| **Product damage** | | Chipping of bricks can occur. | |
| **Financial** | | | |
| **Labour costs** | Low labour costs | High labour costs - "Not a productivity tool" | High labour costs |
| **Capital costs** | High capital cost | High capital cost | Low capital costs |
| **Running costs** | Ongoing maintenance / running costs. | Ongoing maintenance / running costs. | |

## 5. RECOMMENDATIONS

### 5.1. Mechanisation of packing

The general trend within the industry towards mechanisation throughout the production process, and the introduction of automatic dehackers in particular, has resulted in much less manual packing occurring than previously.

- Since manual packing is a high risk activity for musculoskeletal problems then this long-term trend within the industry towards mechanisation of packing should be strongly encouraged.

### 5.2. Mechanisation of setting

The issue of manual handling during setting of green bricks into kiln packs was not directly addressed by this project. However, it is clearly of direct relevance, as setting is the necessary precursor to packing and has many similarities. In the majority of the plants visited, setting has already been mechanised. In the plants where manual setting was observed to occur, there appeared to be little or no absolute necessity for this process to be carried out manually. As green bricks are heavier than fired bricks, problems due to manual handling are also likely to occur among setters.

- Therefore the industry should be seeking to continue the trend towards mechanisation of setting operations as a high priority.

### 5.3. Continuation of manual packing

Due to the nature of some clays and kilns and bricks, manual sorting and packing will need to continue in some circumstances, particularly where waste rates are high or where production volumes are low (eg hand made bricks).

- Therefore it is essential that companies take a proactive approach to management of the associated risks to musculoskeletal health.

### 5.4. Risk assessments

Under Regulations 4 (1) (b) (i) and (ii) of the Manual Handling Operations Regulations 1992, where hazardous manual handling operations cannot reasonably practicably be avoided, employers are required to carry out risk assessments of the manual handling operations and take suitable action to reduce the risk of injury to the lowest level reasonably practicable. These risk assessments are required to take account of a list of risk factors in Schedule 1 of the regulations. Many of these risk factors, such as stooping and trunk twisting, are common features of packing.

HSE have recently published updated Guidance on these Regulations (L23, HSE, 1998) which should be consulted for the Regulations and for information on risk factors and the risk assessment process. Appendix 2 of the Guidance gives an example of a general checklist which can be used as a starting point for detailed risk assessments.

Part of the risk assessment process involves the assignment of levels of risk to the overall task and the individual risk factors identified in the schedule to the MHOR and the associated guidance. The Guidance suggests a 'low' / 'medium' / 'high' categorisation which is simple to understand, but the boundaries between the categories are not defined. A ranking process may be helpful in prioritising areas for improvement.

The quality of manual handling risk assessments seen varied considerably and management in some plants felt that carrying out such assessments was beyond their capability and therefore they had not been carried out. Of the ones that were available, some had been done in house, while others had used external consultants. One plant had carried out a very comprehensive assessment, with a detailed description of the packing task, and included consideration of accident statistics. Some assessments had used the recommendations in the HSE Guidance as a basis. The most limited assessments contained very little information.

- In the light of the risk factors identified in this report and in the Guidance (HSE, 1998), firms should carry out detailed risk assessments and identify possible solutions to the identified problems.
- This should be done by people familiar with the packing process and knowledgeable in the Regulations and risk assessment techniques.
- Use of the checklist in the HSE guidance alone will not be sufficient due to the complexity of the packing task, the high levels of musculoskeletal trouble reported, and the high cumulative loads handled.
- Once changes to workplaces and working practices have been made the risk assessments should be revised to reflect the changes made.
- Risk assessments should be reviewed at regular intervals to monitor the effectiveness of any changes made and the ongoing occurrence of musculoskeletal problems.

Such risk assessments need to start with a proper understanding of the packing process. The process of describing in detail what is involved will highlight important factors and give clues as to possible interventions which can be used to reduce the risk

The following information will be required to carry out a comprehensive risk assessment. It will augment the process of considering the actual risks using the list of factors in Schedule 1 of the Manual Handling Operations Regulations (L23, HSE, 1998):

- Safety policies adopted for manual handling.
- Recruitment and training practices for manual handling tasks.
- Full description of the sorting / packing task, including approved handling techniques and the handling techniques actually in use, and the typical postures adopted.

- Detailed description of sizes and locations of kiln packs / despatch packs / monorail jigs and therefore reach distances and heights.

- Waste / seconds rates and their destinations.

- Description of shift system and break patterns, both nominal and actual and nominal and actual work rates and therefore mean frequency of handling.

- Description of how job rotation is implemented, if used.

- Full description of how workloads vary between different workers.

- Detailed accident/injury history, both reportable under RIDDOR 95 and only recorded in the company accident book, including descriptions of injuries and causes.

- Potential changes to reduce the risks of manual handling operations, and economic considerations.

- Information about people who have abandoned the work within a matter of days and whether any of them suffered injury.

### 5.5. Implementation of changes arising from risk assessments

Clearly, once the risk assessments have identified the problems and potential solutions to them, it is necessary to start implementing these changes. Where manual handling is to continue, even if the long-term aim is to mechanise the task, risk reduction / management should include:

- The improvement of workstations to decrease the amount of reaching, bending and twisting required.

- Organisation of the working day and working week to spread the handling of loads to reduce the risk of cumulative injury occurring.

- The creation of health surveillance systems to monitor the incidence and prevalence of musculoskeletal problems.

- Appropriate and specific training of packers in manual handling techniques suitable for the particular plant.

- Where manual packing is occasionally required in mechanised systems (e.g., when waste rates are abnormally high) then steps should be taken to limit exposure to individual workers.

## 5.6. Workstation design

### *5.6.1. Depth of kiln and despatch packs*

- Where possible these should both be designed so that the packers only have to reach to a maximum depth of two blades at the packing station. This would require mechanical handling of blades of bricks into despatch packs five blades deep before final strapping takes place.

- Long horizontal reaches should be discouraged by design of the workstation.

- In particular, extended horizontal reaches above waist height should be prevented.

- Workers should be encouraged to strip down the front of the pack completely before starting to remove bricks from the back. This will allow workers to stand close to the back of the pack when lifting from it.

Examples of both stripping the front of the pack completely before removing bricks from the back (Figures 10 and 11) and of stripping the pack down in layers (Figure 12) were observed in different plants. In the latter case it was clear that packers were carrying out a lot of lifts at arm's length and often leaning forward to do so. Again this practice was partly dictated by the setting pattern used.

**Figure 10: Packing using a monorail. The fronts of the kiln packs have been stripped down before removing bricks from the rear. Seconds are put in jig pockets and above the jig**

**Figure 11: A monorail with the bottom half of the kiln packs lowered into recesses. The fronts of the kiln packs have been stripped down before removing bricks from the rear.**

**Figure 12: Packers on a monorail removing bricks from the rear of the pack before the front has been stripped down, leading to excessive horizontal reaching**

### 5.6.2. Heights of packs

- When placed at the packing station, kiln packs should be arranged so that they are no higher than about shoulder height. This may necessitate the use of lift tables to control height and ultimately may be solved by rebuilding of kilns.

It is understood that some of the most modern tunnel kilns have very low profiles and use kiln packs which are only a few bricks high. (No plants were seen where lifting occurred much above shoulder height as plants with larger kiln packs used packing methods which meant that lifting at this height was not necessary).

### 5.6.3. Positioning of kiln and despatch packs

Figures 13 to 15 show two contrasting packing systems. In Figure 13 the kiln pack is on the floor and the despatch pack on a low tray. This leads to stooping to reach the lowest heights. In Figures 14 and 15 both packs are on platforms so that their bases are at about knee height, which eliminates stooping to reach the lowest heights.

**Figure 13: Hand packing from kiln packs on the floor to despatch packs on trays with a bent and twisted posture**

- Packs should be positioned so that the packers do not have to reach below knee height when picking bricks from a kiln pack or when placing bricks in a jig or despatch pack. The purpose of this is to reduce stooping.

- Packing to or from packs on the floor or the ground should be eliminated.

Trunk twisting is specifically identified as a risk factor in Schedule 1 of the 1992 Manual Handling Operations Regulations. However, any manual sorting / transfer process will inevitably lead to asymmetric postures being adopted which will usually involve at least some trunk twisting. The perspective of workers engaged in packing was that it was preferable, because it is less tiring, to keep the feet still and adopt asymmetric postures. This asymmetry was often achieved with a combination of upper arm postures and transfer of body weight from one foot to the other (Figures 14 and 15).

- If possible, workstations should be designed to reduce the amount of asymmetric handling required. However, horizontal distance is more important as a risk factor.

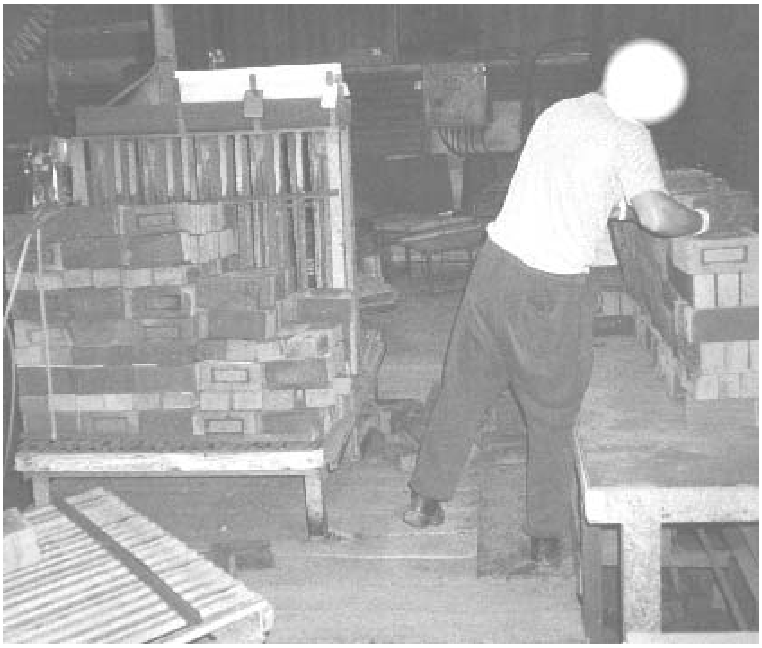

**Figure 14: Hand packing from kiln packs two blades deep to jigs five blades deep. The kiln pack is on a platform to bring its base to about knee height**

**Figure 15: Hand packing from packs two blades deep to jigs five blades deep. The packer has shifted his weight from one foot to the other while moving his hands across in front of his body**

### *5.6.4. Palletising aids*

Mechanical devices such as palletising aids / scissor lifts may have a role to play in reducing bending and twisting by controlling the position of the despatch pack so that the destination of each lift is close to the body and at a suitable height. This would therefore reduce the vertical distance that the load has to be lifted through and also reduce twisting to reach awkward parts of the despatch pack. However, care should be taken when introducing such devices as subtle problems with them may diminish their effectiveness. Drury *et al.* (1983) showed that for a palletiser to be effective in reducing stress on the spine due to manual handling it had to be adjustable for orientation as well as height to eliminate the need for large horizontal reaches across the pallet. Stuart-Buttle (1995) found that subtle barriers created by a raised lip along a conveyor that boxes were being removed from and a rail around the scissor lift and pallet both had the effect of dramatically diminishing the performance of a palletising task and increased the risk of musculoskeletal disorders.

### *5.6.5. Orientation of bricks in packs*

Kiln packs should be designed with the packing methods to be adopted in mind. If inspection policies dictate that each brick is individually inspected or, if to reduce the load lifted in any one lift, it is desired to limit the number of bricks handled, the packs should be designed to facilitate this. Where other kiln pack design considerations permit this, setting bricks on their beds rather than on edge may help achieve this. Figure 16 shows a workstation where the brick orientation made it easy for packers to pick up large numbers of bricks in each lift.

- Packs should be designed to dissuade packers from lifting very large numbers of bricks in a single lift.

- Packs should be designed to allow packers to strip down the front of a pack without having to reach to the back of the pack first, as, for example, in Figures 10 and 11.

### *5.6.6. Packing from kiln cars passing underneath packing stations*

This should be discouraged since it may lead to workers reaching below their feet. It may also cause a tripping hazard from stepping up and down between the kiln car and the packing station. Figure 17 shows an example of how such a set up can also lead to large vertical lift distances. In fact, the normal practice in this plant was for packers to work in pairs to reduce this problem. When they reached the bottom few layers from the kiln cars one would stand on the kiln car and pass bricks up to the other to place in the jig.

### *5.6.7. Thermal environment*

- The thermal environment should be controlled to ensure that extremes of temperature do not occur.

Clearly the environment is easier to control inside a building rather than outdoors, even if, as was seen, roofs are provided to give some shelter. Also, factors such as dust and wind are harder to control in the open air. However, some individuals did express a preference for packing outdoors. Figure 18 shows an individual packing outdoors.

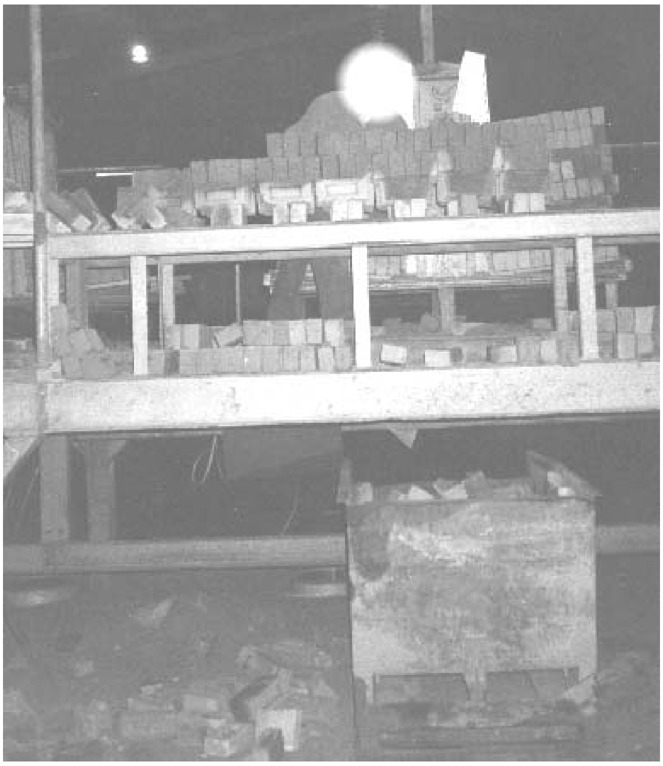

**Figure 16: Hand packing of bricks on a high level platform. Waste bricks go into the skip beneath the platform. The end on orientation of the bricks permits handling of large numbers at once**

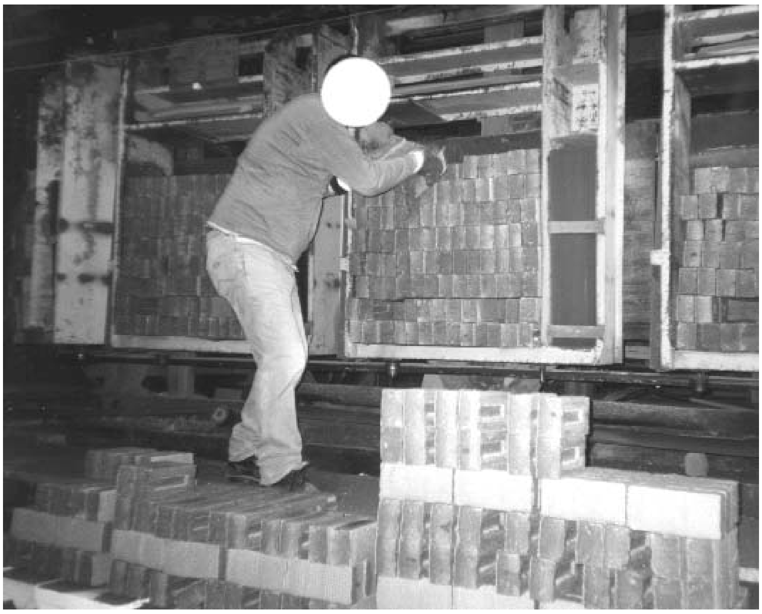

**Figure 17: Packing from kiln cars using a high level monorail. At this point there is a large vertical distance between the start and the finish of the lift**

**Figure 18: Hand packing in the open from kiln packs on the ground to despatch packs on the ground.**

In particular, kiln packs should not be left to cool near packing stations, especially in warm weather. Kiln packs should be allowed to cool adequately before being brought to packing stations. In cold weather kiln packs need not be cooled to ambient temperature but can be used to provide background heating. As packing is an energetic occupation, packers will generate their own body heat and therefore ambient temperatures can be lower than would be expected in an office environment with sedentary workers.

- Ventilation should be provided to prevent excessive temperatures in warm weather.

- If forced ventilation / fans are provided this must not cause localised cooling of muscles which can cause musculoskeletal problems.

## 5.7. Work organisation

### *5.7.1. Shift patterns*

It is important to spread the physical stress on the body from handling bricks over the available work time in order to prevent the rate of damage to the musculoskeletal system exceeding the capacity of the body to repair that damage. A balance must be struck between the physical demands placed on the body and the ability of the body to sustain that load over extended periods. This is based on the same concept as athletic training where athletes regulate the amount of training they carry out in order to avoid overstressing their bodies and entering the so-called ‘overtraining state’ where increased training actually results in performance decreases. It was noted that shift systems had been adjusted at a number of plants with the aim of spreading the load and that a reduction in problems had been attributed to this.

- It is desirable that shift patterns should be operated to avoid lengthy shifts being worked over many consecutive days, particularly when overtime is occurring.

### 5.7.2. *Job and finish / breaks*

The reasons in the previous section applied to shift systems also apply within the working day. If the physical demands of the job are concentrated into only part of the available working day then the risk of cumulative injury will increase. This was reflected by the findings that Job and Finish was more likely to cause back pain and disability due to pain in the wrists / hands. Two monorails visited had moved away from job and finish to a system where they encouraged the workers to take breaks throughout the shift.

- Therefore practices such as job and finish which encourage workers to work excessively fast in order to leave early should be phased out.
- Instead, workers should be encouraged to take regular breaks throughout the day.

The most extreme example seen was a plant where the workers were completing a nominal eight hour shift in about 5.5 hours.

### 5.7.3. *Job status*

Brick packing is a strenuous and physically demanding task which not all members of the working population will have the capacity to carry out. Improving the layout of workstations will make the task easier and therefore increase the proportion of the population capable of carrying out the task. It was noted that the status of packing differed between plants. In some plants packing was seen as a high status job with better pay than other production jobs. In other plants packing was the entry job with the same pay as other production workers. Such differences in status are likely to affect workers' attitudes towards the job and will affect actual rates and reported rates of work-related musculoskeletal disorders.

### 5.7.4. *Competitive behaviour*

In one plant, due to the system by which bricks were brought to the packing stations, competition occurred among the packers to complete each pack as quickly as possible to avoid having to wait for more bricks while bricks were being delivered to other workstations.

- Competition among packers should be discouraged, particularly where faster packing by an individual can affect the ability of another individual to meet his target.

### 5.7.5. *Maximum brick limits*

A possible approach to the problems of workers overstressing their wrists by lifting excessive numbers of bricks at one time might be to impose a maximum brick lift which depended upon the weights of the bricks. Thus if a maximum of 10 kg was imposed, at plants where the bricks weigh between 2 and 2.5 kg the limit would be 4 bricks, but at plants where bricks weigh 1.8 to 2 kg 5 bricks could be handled at once. If this was done by redesigning the packs so that they were a multiple of the MBL wide this would encourage packers to pick up that number of bricks. Other approaches might be needed for non-standard bricks such as 73 mm high bricks, or if the design of bricks were to change dramatically.

### *5.7.6. Team work*

In hand packing systems each individual is responsible for packing his own bricks and can therefore usually work at his own rate without being concerned about the rate at which his colleagues are working. This allows him to take into account his own capabilities and motivators such as piece work or job and finish. On a monorail, by contrast, the machine has to either operate at a pace the slowest worker can cope with (and the slower workers have to be able to learn to keep up within the induction period or leave packing) or the faster workers 'carry' the slower workers.

The general consensus during the visits was that monorail packers have to operate as a team to ensure that each individual does his share of the work and that the work is done at an acceptable speed. Also, the practice at all of the monorails visited was for workers to rotate round the monorail over the course of the shift to ensure that each individual was able to pack to a range of heights.

- Therefore teamwork and rotation should be actively encouraged on monorails.

## 5.8. Preemployment / placement screening / ongoing monitoring

There is little evidence that preemployment screening of workers being assigned to physically demanding work has much potential to predict which individuals are at risk of developing musculoskeletal disorders. A wide-ranging review by Jackson (1994) discussed, in the US legal context, the need for evidence to show that preemployment screening programs are scientifically justified. This was largely related to tests which attempt to predict which workers would be capable of performing various physically demanding jobs. Such tests require 'criterion validity', i.e., performance on the test must predict job performance. They must also have 'content validity', i.e., the tests must represent the actual job, and 'construct validity', i.e., the tests must measure the degree to which candidates have identifiable characteristics that are important for successful job performance.

Another review by Shepherd (1992) concluded that preplacement evaluations that attempted to imitate the demands of the employment proved useful but that true preemployment examinations (those taking place before the worker is offered a job) did not aid either the employer or the worker or the studies did not show a positive benefit. A number of explanations have been offered for this lack of evidence (Bigos *et al*., 1992). These include the facts that the predictive ability of factors associated with back pain is very poor; that back pain does not fit well into an injury model due to its high prevalence and recurrent, episodic nature and that the ability to predict chronic problems is as important as the prediction of acute cases.

Troup *et al.* (1987) showed that tests to determine maximum acceptable weights for handling tasks were not of general value in preemployment screening to try to prevent low back pain.

- Development of preemployment tests to predict job performance and hence risk of injury is a major undertaking with definite limitations. It would be unreasonable to expect a relatively small industry such as the brick manufacturing industry to do this.

- Since it is widely recognised that the best predictor of risk of back pain, or other musculoskeletal injury, is a previous history of back pain or other injury (Chaffin *et al*., 1999) then some kind of medical screening or health examination to identify individuals with existing or recurrent musculoskeletal problems should be considered.

- Screening should include preemployment / preplacement medical screening of new employees or existing employees being transferred to packing duties.

- Regular screening of existing packers should also occur to monitor their health status and to detect early signs of musculoskeletal disorders.

- Such screening should include a clinical examination of the musculoskeletal system, particularly the wrists and low back. A preemployment questionnaire could be used to help establish whether the individual has a history of musculoskeletal problems, but would not be sufficient by itself.

Suitable individuals to carry this out screening could be either a registered medical practitioner or nurse with experience in dealing with musculoskeletal disorders, or a member of the Chartered Society of Physiotherapy.

### 5.9. Manual handling training

- When changes are made to packing practices and / or workstation design existing packers should be trained in the new techniques required by a competent person with a knowledge and understanding of the industry.

If external consultants or trainers are used it must be borne in mind that the manual handling training courses that are available are usually general in nature and would need to be tailored to the specific circumstances of this industry.

- Once training has been carried out, the techniques actually adopted by the packers should then be monitored to assess the effectiveness of the changes and the training, and the views of the packers should be taken into account.

Where feasible, the shift foreman or monorail operator could be given responsibility for training new packers in the approved method of packing in the plant. This would require ensuring that the person doing the training accepts the approved method of packing and has the necessary skills in training to be able to teach the trainees effectively.

## 6. ACKNOWLEDGEMENTS

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# 8. APPENDIX 1: STATISTICAL TERMINOLOGY

This report makes extensive use of statistical tests and associated terminology. For ease of reference and understanding, some brief definitions are given below:

***Mean value***

This is the arithmetic mean of a set of values. It is what is usually meant by the term 'average'.

***Standard deviation (SD)***

This is a measure of the spread of a set of values around its mean value.

***Standard Normal Deviate (SND)***

This is a measure of the distance from the mean of a particular value. The distribution the value belongs to is assumed to be a Normal, or Gaussian (bell-shaped), distribution with a mean of zero and a standard deviation of 1.0. 95% of the values will fall between a SND of +1.96 and an SND of -1.96.

***Significance test***

The purpose of a statistical test is to find the likelihood that variations in the collected data are the result of random processes. Thus a comparison between two groups would seek to show whether any difference between the two groups was a real difference or due to random variations in the measurements. This would normally be done by estimating the probability that the difference was due to random variation. The resultant probability would be expressed as either a decimal or as a percentage.

A number of different tests exist which are used in different circumstances. The appropriate test statistic is calculated from the data and the associated probability can then be obtained from standard tables. The relationships between the test statistics and the probabilities are normally too complex to be calculated directly except by computer.

Conventionally, probabilities of less than 5% ('$P < 0.05$') are regarded as 'statistically significant'. In other words, if there is less than one chance in twenty that the differences between measurements are due to random error, then it is accepted that there is a real difference. Probabilities of more than 5% are described as non-significant ('NS'), i.e., the observed differences are reasonably likely to have occurred by chance. When a more stringent criterion is required then a probability of 1% ('$P < 0.01$'), i.e., less than one chance in a hundred, is used. The rule is that the smaller the probability that the difference occurred by chance, the more important the finding.

Once a statistically significant finding has been obtained it is necessary to examine the size of the difference (the effect size) found in order to determine its importance. This is because statistical significance depends on the sizes of the samples being compared and therefore a large sample can show a small difference to be significant, even though in absolute terms it may be of no practical significance.

***Power***

This is the ability of a statistical test to detect a real difference between two groups of data. It depends on the size of the difference and the number of measurements made (the sample size), i.e., the larger the sample, the more powerful the test. Conventionally, a power of 80% to detect a difference significant at the $P < 0.05$ level is considered the minimum necessary. If insufficient data are collected then the probability increases that the test being used shows there is no difference when there really is one. In other words, lack of power means that real differences appear to be not significant.

### *Degrees of freedom (DF)*

This is a number associated with a statistical test showing how many different ways the data are free to vary randomly. It depends on the number of measurements made. It affects the relationship between the calculated test statistic and the associated probability.

### *Student's t-test*

This is a statistical test which allows the comparison of the means of two sets of numeric data by finding the probability that the difference between the means is due to chance and hence whether the difference is significant. It would be suitable for comparing the mean heart rates of two groups of workers. An *unpaired* t-test compares two sets of independent data. A *paired* t-test compares two sets of data where each observation in one set is paired with an observation in the other set.

### *Correlation coefficient (r)*

A correlation coefficient is a measure of the degree of association between two variables. In other words, it shows how much changes in one variable are linked to changes in another variable. The Pearson correlation coefficient (r) ranges between -1.0 (perfect inverse correlation) through 0.0 (no correlation) to +1.0 (perfect correlation). Linear correlation creates equations of the form: Y = constant + coefficient × X.

### *Proportion of variance accounted for ($R^2$)*

$R^2$, the square of the Pearson correlation coefficient, measures the amount of the variability ('variance') of two variables that is accounted for by the correlation between the two variables. It is usually expressed as a percentage. An $R^2$ value of 100% equates to an r value of 1.0; an $R^2$ value of 50% relates to an r value of 0.707; an $R^2$ value of 0% relates to an r value of 0.0.

### *$\chi^2$ (Chi-squared) test*

This is a statistical test that can be used to compare the frequencies of occurrence of non-numeric data, such as the frequencies of yes / no answers to a question. It does this by comparing the observed frequencies with the expected frequencies in order to calculate the $\chi^2$ statistic which is then used to find the probability that the difference is due to chance and hence the significance of the difference in frequencies.

### *Contingency table*

A table showing how answers to two separate questions are distributed among the possible combinations of responses to the two questions. An example would be a table showing how many workers on hand packing or on monorails are right handed, left handed, or ambidextrous (Table 15).

### *Prevalence*

This is the frequency of occurrence of existing cases of a problem, such as back pain. 'Point prevalence' is the proportion 'affected now'. 'Period prevalence' is the proportion 'affected over the last x' days/weeks/months.

Episodes of musculoskeletal disorders, such as back pain, typically get better over a relatively short period of time, unlike diseases such as asthma which are chronic (long term). Prevalences of musculoskeletal disorders increase as the reporting period increases because the chance of an individual having been affected increases with time. Thus more people will have had back pain in the last year than will have had it in the last week.

Problems of recall increase with the length of the period being asked about, especially with problems of short duration which are more likely to be forgotten. Therefore, prevalence reports of problems such as back pain within the previous week will be more reliable than reports of problems within the last year.

***Incidence***

This is the frequency of occurrence of new cases of problems such as back pain, i.e., the number of new cases in a defined time.

***Relative risk***

If the frequencies of occurrence of a particular problem are known in two situations or in two groups, it is possible to compare these values as a 'relative risk'. This is done by dividing one by the other to give a ratio. Thus if the prevalences of a problem such as low back pain are known in two different groups of workers it is possible to say how much more likely one group is to suffer back pain by dividing one prevalence by the other prevalence. Thus, if one group has a prevalence of 60% and the other has a prevalence of 30% the relative risk is 200% because the first group is twice as likely to suffer the problem.

***Factorial design***

This is a method of collecting measurements that ensures that measurements are taken for all possible combinations of the factors being studied. Thus in a 2 × 2 factorial design a total of four combinations would be possible. If the factors are A and B and have levels 1 and 2 the four combinations would be A1B1, A1B2, A2B1 and A2B2.

# 9. APPENDIX 2: INFORMATION SHEETS, CONSENT FORM AND QUESTIONNAIRE

## STUDY OF MANUAL BRICK SORTING / PACKING IN THE BRICK PRODUCTION INDUSTRY

## INFORMATION FOR PARTICIPATING COMPANIES

The Health and Safety Executive (HSE) and the British Ceramics Confederation (BCC) have asked the Health and Safety Laboratory (HSL) to look at manual sorting and packing of bricks in the brick production industry. This is because of concern about the risks of musculoskeletal disorders being caused by this task. This study has been approved by the HSE Research Ethics Committee and has received Ministerial approval under Government survey control procedures. Trade Unions (GMB and TGWU) have been asked to cooperate with this study.

**What we will do**

We intend to observe brick sorters / packers carrying out their normal tasks during a normal shift. The aim is to not disrupt production. Measurement will take place on one day only. We will pay a preliminary visit to each site to discuss the project with local Management and Trade Unions and to enable us to plan the measurement visit properly.

**What we will measure**

<u>Questionnaires</u>

At the start of the shift we will ask all the packers / sorters to fill in a standard questionnaire which HSE have used widely in the past. This asks if the individual has, in the past, experienced ache, pain, discomfort or numbness in a number of different parts of the body, and if this has prevented him from carrying out normal activities. At the end of the shift we will ask all the packers to rate their physical exertion and any discomfort experienced during the shift.

<u>Heart rate / video</u>

We will measure heart rates from up to four packers over the shift. We will do this with Polar heart rate monitors. These consist of a transmitter attached either to a chest strap or to disposable electrodes, and a wristwatch receiver to store the heart rate. We will video the workers whose heart rates are being measured as they do their work for the duration of the shift. We will also take some still photographs. The video and photographs will be used to assess the postures workers adopt as they pack bricks. Obviously, we might also film or photograph other workers by accident when we are filming these workers.

**Participation**

We are required to make sure that participation is voluntary. Workers must not be forced in any way to fill in the questionnaire or to have their heart rates measured. Workers must be free to drop out of the study at any point without giving a reason.

We estimate that explaining the purpose of the study to the participants and filling in the questionnaires and attaching heart rate monitors should take no more than half an hour in total.

You should note that we (HSE) are not legally liable to pay compensation, for damage, loss or injury resulting from taking part in this study, if there has been no negligence on our part.

**Use of collected data**

We will keep the questionnaire and heart rate data for at least ten years. We will not keep information which could identify individual workers on computer. We will not let people outside HSE have access to data from individuals. HSE reports and any external publications or presentations will be about groups of workers, not identifiable individuals. Individual workers can have copies of their own data if they wish. Individual firms will be allowed access to information about their sites. It is intended to feed back the results of the whole study to the industry via the British Ceramics Confederation.

**Use of photographs and video material:**

We will keep photographs and video for at least ten years. Each photograph will have a code number. Individuals will be allowed to have copies of any photographs they appear in.

1. We may want to use photographs of individuals in publications or presentations.
2. If we do so, we will do our best to make sure that individuals cannot be recognised, but it is possible that somebody may still recognise them.
3. We can only use photographs or video material of individuals with their consent.
4. We can only use photographs or video material with the consent of the firm where they were taken.

**Contact address**

If you have questions about the way we carry out this study you can contact the Medical Secretary of the HSE Research Ethics Committee, Dr R. Rawbone, directly on 0151 951 4555

We will be willing to answer questions about the study at the time of the study. If you want to contact us afterwards, the address is:

Mr Andrew Pinder
Health and Safety Laboratory
Broad Lane
Sheffield
S3 7HQ
Tel 0114 289 2594
Fax 0114 289 2526
email Andrew_Pinder@hsl.gov.uk

## STUDY OF MANUAL BRICK SORTING / PACKING IN THE BRICK PRODUCTION INDUSTRY

### INFORMATION FOR VOLUNTEERS

The Health and Safety Executive (HSE) and the British Ceramics Confederation (BCC) have asked the Health and Safety Laboratory (HSL) to look at manual sorting and packing of bricks in brickworks. This is because of concern about the risks of musculoskeletal disorders (giving rise to aches, pain and discomfort) being caused by this task. This study has been approved by the HSE Research Ethics Committee. Your employer and trade unions have agreed to cooperate.

**What we will do**

We intend to observe brick sorters / packers carrying out their normal tasks during a normal shift.

**What we will measure**

<u>Questionnaires</u>

At the start of your shift we will ask you to fill in a questionnaire. This asks if you have, in the past, experienced ache, pain, discomfort or numbness in a number of different parts of your body, and if this has prevented you carrying out your normal activities. At the end of the shift we will ask you to rate your level of physical exertion and any discomfort you experienced during the shift.

<u>Heart rate / video</u>

We will also measure, over the shift, heart rates from up to four of you. We will do this with Polar heart rate monitors. You will wear a transmitter attached either to a chest strap or to disposable electrodes, and a wristwatch receiver to store your heart rate. We will also video you doing normal sorting / packing activities throughout the shift. We may also take still photographs. We might film or photograph other workers by accident when we are filming the workers whose heart rates are being monitored.

**Participation**

You do not have to take part in the study and your job will not be affected in any way if you do not.

Taking part in the study should not change the way you do your job. Filling in the questionnaires and attaching heart rate monitors may mean that you finish your shift slightly later than normal.

You can pull out from the study at any point by telling us to stop taking measurements from you. You do not have to say why.

You should note that we (HSE) are not legally liable to pay compensation, for damage, loss or injury resulting from taking part in this study, if there has been no negligence on our part.

**Use of collected data**

We will keep the questionnaire and heart rate data for at least ten years. We will not keep information which could identify you on computer. We will not let people outside HSE have access to data from individuals. HSE reports and any external publications or presentations will be about groups of workers, not identifiable individuals. You can have copies of your own data if you wish.

**Use of photographs and video material:**

We will keep photographs and video for at least ten years. Each photograph will have a personal code number, but not your name. If you want, you can have a copy of any of your photographs.

We will use the video to record your posture and activities while we are measuring your heart rate. You can see your own video footage if you wish.

1. We may want to use photographs of you in publications or presentations.
2. If we do so, we will do our best make sure you cannot be recognised, but it is possible that somebody may still recognise you.
3. We therefore seek your consent to use photographs/video material of you since we can only use them with your permission. We fully understand if you do not want your pictures to be used and the consent form allows you to indicate this.

**Your questions**

If you have questions about the way we carry out this study you can contact the Medical Secretary of the HSE Research Ethics Committee, Dr R. Rawbone, directly on 0151 951 4555

We will be willing to answer questions about the study at the time of the study. If you want to contact us afterwards, the address is:

Mr Andrew Pinder
Health and Safety Laboratory
Broad Lane
Sheffield
S3 7HQ
Tel 0114 289 2594
Fax 0114 289 2526
email Andrew_Pinder@hsl.gov.uk

## 9.1. Consent form

Reference number.......................................

**VOLUNTEER CONSENT FORM**

**I, ...........................................................** *(name in block capitals)* **agree to participate in the**

**HSL study of MANUAL HANDLING IN BRICK SORTING / PACKING.**

I have read the INFORMATION FOR VOLUNTEERS and understand what I am expected to do as a volunteer. **........... (initial here)**

I am willing to complete a questionnaire about musculoskeletal aches and pains I may have experienced in the last year and to give ratings of exertion and discomfort related to my job.
**........... (initial here)**

I am willing for my heart rate to be monitored and video recordings made while I am performing my normal work.. **........... (initial here)**

I understand that with my agreement photographs and video material recorded during the study may be used for illustration purposes in HSE reports and any subsequent journal articles. This is on the understanding that, while every effort will be made to preserve my anonymity, this cannot be guaranteed. The reasons for this are explained overleaf.

**I do/do not agree to this use of photographic and video material**
**........... (delete as appropriate and initial here)**

I understand that I may withdraw from this study at any time, without giving a reason.

**SIGNATURE ........................................... DATE ..........................**

Volunteers should note that HSE has no legal liability to pay compensation, for damage, loss or injury resulting from participation in this study where there has been no negligence on the part of HSE.

| |
|---|
| This project has been cleared to proceed by the HSE Research Ethics Committee. If you have any concerns over the conduct of the study you may contact the Medical Secretary of the Research Ethics Committee directly on 0151 951 4555.<br><br>Signed .................................................... Date : .......................................<br>(Dr P Graham, Chair to the HSE Research Ethics Commitee) |

I am an ergonomist working as a researcher for the Health and Safety Laboratory, part of the Health and Safety Executive, and I am bound by the code of conduct for European Ergonomists drawn up by the Centre for Registration of European Ergonomists.

Signed ........................................................... (Mr Andrew Pinder, project leader)

**Use of photographs and video material:**

We will keep photographs and video for at least ten years. Each photograph will have a personal code number, but not your name. If you want, you can have a copy of any of your photographs.

We will use the video to record your posture and activities while we are measuring your heart rate. You can see your own video footage if you wish.

1. We may want to use photographs of you in publications or presentations.
2. If we do so, we will do our best make sure you cannot be recognised, but it is possible that somebody may still recognise you.
3. We therefore seek your consent to use photographs/video material of you since we can only use them with your permission. We fully understand if you do not want your pictures to be used and the consent form allows you to indicate this.

## 9.2. The NMQ

HSE Health & Safety Executive

1-4 Ref ☐☐☐☐ 5 Rec [1] 6/8 Site ☐☐☐ 9/12 SIC Activity ☐☐☐☐

## MUSCULOSKELETAL DISORDERS

Dear Sir / Madam,

This questionnaire has been prepared by the Health and Safety Executive which is the UK organisation responsible for health and safety at work.

With the co-operation of your employer and trade unions we are conducting a survey to find out the extent to which muscle and joint aches and pains are experienced by employees in your occupation.

We are interested in mild and severe problems affecting muscles, ligaments, nerves, tendons, joints and bones suffered both at work and away from work. This could mean sprains, strains, inflammations, irritations and dislocation. For the purpose of this survey we are not interested in any injuries to the skin.

We would like you to complete this questionnaire about your health. All answers will be treated as **strictly confidential** and individual answers will not be made known to anyone other than the survey team.

The more questionnaires that are completed, the greater will be the accuracy and usefulness of the findings, the better to help us improve health and safety at work. Thank you for your help.

Epidemiology and Medical Statistics Unit (EMSU), Magdalen House, Trinity Road, Bootle, Merseyside L20 3QZ.

HOW TO ANSWER THE QUESTIONNAIRE

Please complete this questionnaire by answering ALL questions as fully as possible. Some of the questions require a written answer, for others you need only tick a box. ☑

Please do not write in the margin.

## PERSONAL DETAILS

**1** Date of birth — Day ☐☐ Month ☐☐ Year ☐☐ 13-18

**2** Sex — Male 1 ☐ Female 2 ☐ 19

**3** Today's date — Day ☐☐ Month ☐☐ Year ☐☐ 20-25

**4** What is your weight? 26-27

stones ☐ + pounds ☐ or kg ☐ 28-29

**5** What is your height? 30

feet ☐ + inches ☐ or cm ☐ 31-32

**6** Are you right or left handed? 33

right 1 ☐ left 2 ☐ able to use both hands equally 3 ☐

## ABOUT YOUR JOB

7 What is your job title? 34-56

8 How many years and months have you been doing your **present type of work** at this site? 57-58

Years + Months — If less than one month, how many weeks? 59-60 61

9 Have you worked elsewhere doing a similar type of work? 62

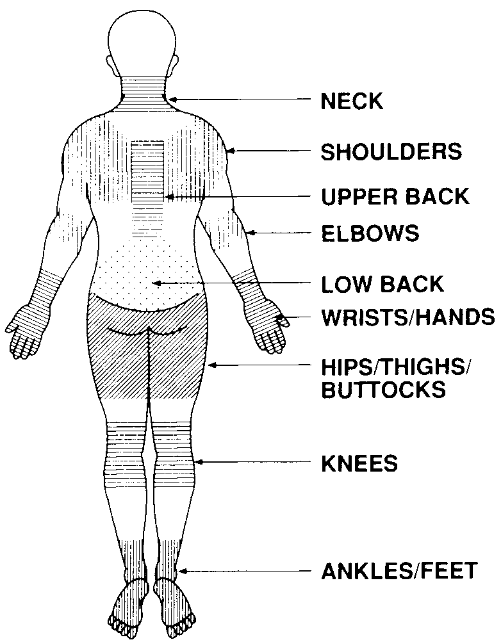
No 1 ☐ Yes 2 ☐

**9.1 If yes,** what is the total length of time you worked elsewhere, doing a similar type of work before starting at this site? 63

1 ☐ Years
2 ☐ 1-2 years
3 ☐ 3-4 years
4 ☐ 5-9 years
5 ☐ 10 years or more

**10** On average, how many hours a week do you work (including overtime but excluding main meal break)? 64-65

Hours




This picture shows how the body has been divided. Please answer the three questions shown opposite for each body area.
Body sections are not sharply defined and certain parts overlap. You should decide for yourself which part (if any) is or has been affected.

## MUSCULOSKELETAL DISORDERS

1-4 Ref [ | | | ] 5 Rec [2]

Please answer all questions numbered **6** to **32** by using the tick boxes ☑ - *one tick for each question*

Please note that this part of the questionnaire should be answered, even if you have never had trouble in any part of your body.

| Have you at any time during the **last 12 months** had **trouble (such as ache, pain, discomfort, numbness)** in: | Have you had **trouble** during the **last 7 days:** | During the **last 12 months** have you been **prevented** from carrying out normal activities (eg job, housework, hobbies) because of this trouble: |
|---|---|---|
| 6 ***Neck***<br>No 1 ☐ Yes 2 ☐ | 7 ***Neck***<br>No 1 ☐ Yes 2 ☐ | 8 ***Neck***<br>No 1 ☐ Yes 2 ☐ |
| 9 ***Shoulders***<br>No 1 ☐ Yes 2 ☐ in the right shoulder<br>3 ☐ in the left shoulder<br>4 ☐ in both shoulders | 10 ***Shoulders***<br>No 1 ☐ Yes 2 ☐ in the right shoulder<br>3 ☐ in the left shoulder<br>4 ☐ in both shoulders | 11 ***Shoulders (both/either)***<br>No 1 ☐ Yes 2 ☐ |
| 12 ***Elbows***<br>No 1 ☐ Yes 2 ☐ in the right elbow<br>3 ☐ in the left elbow<br>4 ☐ in both elbows | 13 ***Elbows***<br>No 1 ☐ Yes 2 ☐ in the right elbow<br>3 ☐ in the left elbow<br>4 ☐ in both elbows | 14 ***Elbows (both/either)***<br>No 1 ☐ Yes 2 ☐ |
| 15 ***Wrist/hands***<br>No 1 ☐ Yes 2 ☐ in the right wrist/hand<br>3 ☐ in the left wrist/hand<br>4 ☐ in both wrists/hands | 16 ***Wrist/hands***<br>No 1 ☐ Yes 2 ☐ in the right wrist/hand<br>3 ☐ in the left wrist/hand<br>4 ☐ in both wrists/hands | 17 ***Wrist/hands (both/either)***<br>No 1 ☐ Yes 2 ☐ |
| 18 ***Upper back***<br>No 1 ☐ Yes 2 ☐ | 19 ***Upper back***<br>No 1 ☐ Yes 2 ☐ | 20 ***Upper back***<br>No 1 ☐ Yes 2 ☐ |
| 21 ***Lower back (small of back)***<br>No 1 ☐ Yes 2 ☐ | 22 ***Lower back***<br>No 1 ☐ Yes 2 ☐ | 23 ***Lower back***<br>No 1 ☐ Yes 2 ☐ |
| 24 ***One or both hips/thighs/buttocks***<br>No 1 ☐ Yes 2 ☐ | 25 ***Hips/thighs/buttocks***<br>No 1 ☐ Yes 2 ☐ | 26 ***Hips/thighs/buttocks***<br>No 1 ☐ Yes 2 ☐ |
| 27 ***One or both knees***<br>No 1 ☐ Yes 2 ☐ | 28 ***Knees***<br>No 1 ☐ Yes 2 ☐ | 29 ***Knees***<br>No 1 ☐ Yes 2 ☐ |
| 30 ***One or both ankles/feet***<br>No 1 ☐ Yes 2 ☐ | 31 ***Ankles/feet***<br>No 1 ☐ Yes 2 ☐ | 32 ***Ankles/feet***<br>No 1 ☐ Yes 2 ☐ |

**REMEMBER** - Please check you have answered questions 6 to 32

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

## 9.3. The RPE scale

## Rating of Perceived Exertion (RPE)

Please mark on this scale the number that matches how hard you think your job is overall:

| | |
|---|---|
| **6** | |
| **7** | **Very, very light** |
| **8** | |
| **9** | **Very light** |
| **10** | |
| **11** | **Fairly light** |
| **12** | |
| **13** | **Somewhat hard** |
| **14** | |
| **15** | **Hard** |
| **16** | |
| **17** | **Very hard** |
| **18** | |
| **19** | **Very, very hard** |
| **20** | |