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Prospective evaluation of the 1991 NIOSH Lifting Equation

Prepared by the **Health and Safety Laboratory**
for the Health and Safety Executive 2011

RR901
Research Report

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Prospective evaluation of the 1991 NIOSH Lifting Equation

Andrew DJ Pinder PhD
Gillian A Frost
Harpur Hill
Buxton
Derbyshire
SK17 9JN

An epidemiological prospective cohort study of the ability of the 1991 NIOSH Lifting Equation to predict loss of time from work due to low back pain (LBP) or to predict reports of LBP followed 515 industrial workers in jobs requiring manual handling for 18 months. Baseline measurements were made of their jobs, histories of musculoskeletal trouble and of psychosocial variables. Longitudinal analysis of tasks was based on 367 subject/job combinations.

The strongest predictor of future LBP was a history of LBP. No relationship was found between the Composite Lifting Index (CLI) and either the incidence of lost time due to LBP or the prevalence of LBP (adjusted Hazard Ratio (HR) = 1.0, 95% Confidence Interval (CI) 0.9 – 1.1). The CLI is not useful as a method for assessing risk of LBP due to manual handling.

The maximum value of the Single Task Lifting Index (STLI) gave an adjusted HR of 1.1 (95% CI 0.9 – 1.4). It too is not useful as a method for assessing risk of LBP due to manual handling.

There is a need to develop better methods of assessing risk of LBP from manual handling, focusing on ways of combining risk factors and exposure to multiple tasks.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

HSE Books

First published 2011

ACKNOWLEDGEMENTS

This study was based upon a protocol developed by Texas Tech University and Liberty Mutual Research Institute for Safety in the USA. Thanks are therefore particularly due to Dr. Patrick Dempsey then at Liberty Mutual for allowing this study to use that protocol.

This work was funded by HSE as part of its research programme into manual handling and musculoskeletal disorders. Thanks are due to the many current and former HSE staff who have had an input into the project, particularly Mr. Len Morris, Mr. Mike Gray, Mr. John McElwaine, Dr. Roger Rawbone, Mr. Malcolm Darvill, Dr. Claire Dickinson, Mr. Chris Quarrie and Mr Kevin Mantle.

Thanks are due to Dr Lesley Rushton, now of Imperial College London, for epidemiological advice.

Thanks are due to HSL colleagues for assisting with company and subject recruitment, data entry and follow-up, particularly Mrs Kay Jackson, Mr. Matthew Birtles, Mr. Edmund Milnes, Mr. James Bunn, Ms Kath Travis and Ms Clare Lawton. Thanks are due to Mr Sean Sankey for assistance in data reduction of video.

Thanks are due to the many companies and individuals who were contacted to ask if they would be willing to participate in this project and especially those that had suitable jobs and that were willing to participate in the longitudinal phase of the project.

FOREWORD

The most important findings of this report can be found in the Abstract. There is a more detailed Executive Summary on Page xv. It is suggested that an initial reading of the detail of the study should concentrate on Section 4, the Design of the study, Section 8, the Summary of results of analysis of the risk of LBP, and Section 11, the Discussion of the findings.

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EXECUTIVE SUMMARY

Background

The 1991 revised NIOSH Lifting Equation is a method proposed in the USA for evaluating and designing lifting tasks intended to help reduce the incidence of low back injuries in workers. It was a revision of an earlier lifting equation published in 1981 by NIOSH. The 1991 equation calculates a Recommended Weight Limit (RWL) for each lifting task that a worker performs. This is done using the start and end positions of the load, the asymmetry of the lift, the frequency of lifting and the nature of the hand-object coupling. The task weight is divided by the RWL to give a Single Task Lifting Index (STLI) for the task. A Composite Lifting Index (CLI) is obtained for each individual by combining the STLIs from the various tasks that a worker performs through a working shift. It therefore serves as a measure of overall load on the worker. Equations based on the 1991 NIOSH lifting equation have been published in European (BS EN) and International (ISO) Standards.

The purpose of this study was to carry out in the United Kingdom an epidemiological prospective cohort study of the capability of this equation to predict the incidence and severity of low back disorders. It was designed as a replication of a study carried out in the USA by the Liberty Mutual Research Institute for Safety.

Objectives

1) To prospectively determine if the Lifting Index (LI) for jobs from various industries is related to the incidence and severity of low-back disorders. The LI is the ratio of actual weights lifted to the Recommended Weight Limit (RWL) which arises from applying the 1991 revised NIOSH lifting equation.

2) To prospectively determine if the relationship between the LI value and the probability of low back injury is different for workers of different sex, age, height, weight, and history of previous low-back pain or injury.

3) To similarly evaluate how the requirements in the current ISO and CEN proposals for standards on manual handling are related to the incidence and severity of low-back disorders.

4) To empirically determine relationships between vertical distance (V), horizontal distance (H), lift distance (D) and asymmetry (A), and the incidence of back injuries. To compare these relationships with that of the functional forms of the equivalent multipliers in the NIOSH lifting equation (and their ISO/CEN equivalents). Similar comparisons of frequency and level of hand to object coupling will also be carried out.

5) To determine if an alternate injury predictive model developed from the data collected could either replace or supplement the NIOSH equation.

Main Findings

Subjects were 515 workers employed in industrial jobs requiring regular and consistent manual handling. They were recruited from 19 plants belonging to 12 firms involved in general manufacturing, engineering, pharmaceuticals, parcel distribution, warehousing, leather processing and food processing. Baseline measurements were made of their jobs, of their history of musculoskeletal trouble and of psychosocial variables. They were followed up for 18 months at three month intervals to record the dates of episodes of lost time due to LBP and reports of LBP that did not result in lost time.

No LBP or injury follow-up data were obtained for 17 individuals (3.3%), leaving a sample of 498 participants for whom longitudinal data were recorded and followed-up for a total of 230,789 person-days. Of the recruited participants, 416 were male and 99 (19.2%) were female. There were 151 dropouts (29.3%) with between 17 and 34 occurring per quarter, giving an annual dropout rate of 19.5%. Of the 151 dropouts, 104 were due to individuals changing to a job outside the study. Injury resulted in 15 dropouts, illness caused nine, and four females dropped out due to pregnancy. Another 31 participants changed to another job within the study so were kept in the study.

The longitudinal analyses were based on personal and outcome data for all 515 subjects but on task data for only 346 of the 515 subjects recruited. During the study twelve subjects transferred between jobs included in the subjects so were included twice in the longitudinal analysis, giving a total of 358 subject-job combinations.

The strongest predictor of future episodes of LBP was a history of LBP. Participants who lost time due to LBP before the study had nearly seven times the risk of experiencing an episode of lost time during the study as those who had no LBP before the study (HR = 6.6, 95% CI 3.5 – 12.2).

The psychosocial variables of ‘Influence and control over work’, and ‘Supervisor climate’ showed significant negative association with risk of lost time due to LBP during the study. After adjustment for age, gender and LBP experience before the study, the relationship between risk of lost time due to LBP during the study and a poor perception of ‘Supervisor climate’ remained statistically significant (P = 0.038 for the continuous model).

Almost all jobs included in the study involved more than one manual handling task. It was therefore necessary to use the CLI as the primary predictor variable. The maximum value of the STLI was used as a secondary predictor as this can be taken as a measure of peak loading.

No relationships were found between the CLI and either the incidence of lost time due to LBP or the prevalence of LBP. The crude Hazard Ratio (HR) for the CLI obtained from a continuous model using Cox regression was 1.0, (95% Confidence Interval (CI) 0.9 to 1.1), indicating no increase in risk. Adjusting for covariates such as weight did not change these figures. Identical HRs were found for reporting of LBP.

The confidence in the finding that there was no increase in risk with an increase in the CLI is high because of the very narrow CIs. This means that the CLI is not useful as a method for assessing risk of LBP due to manual handling.

Analysis of the maximum STLI gave a crude HR of 1.0 (95% CI 0.8 – 1.3). The adjusted HR of 1.1 (95% CI 0.9 – 1.4) indicated a small, non-significant increase in risk. This means that the maximum STLI also does not predict absence due to LBP so is also not useful as a method for assessing risk of LBP due to manual handling.

Examination of the effects of the task variables that contributed to the maximum STLI showed an increase in risk of lost time as the maximum horizontal hand distance increased (P = 0.01). While age itself was not a significant risk factor, there were a number of statistically significant interactions between age and task variables, meaning that the measured effect of these variables depended on the age of the participants.

The CLI is calculated by taking the largest STLI and incrementing it for each subsequent task, adjusting to take account of the increase in overall frequency of handling. It was found that this process can lead to the average lift being assessed as more severe than any individual lift and as more severe than just increasing the frequency for the worst single task.

It was found that the order in which tasks are added affects the CLI value obtained. While the CLI formula involves adding changes in the LI as tasks are added, it is not commutative in the way that normal addition is. Reducing a parameter in a job with two tasks meant that the STLI for the previously more severe task decreased, making it the less severe task. As a result, the second, unchanged, task entered the CLI calculation first. Despite the severity of the job decreasing, the CLI actually increased.

The ISO equation is effectively identical to the 1991 NIOSH equation. The EN equation has added three multipliers representing one-handed handling, two person handling and additional tasks. Neither equation provides a method for compositing multiple tasks so neither has an equivalent to the CLI so could not be used to obtain a measure of overall load on the person. . However, the values that they calculate are conceptually similar to the STLI. It is therefore immediately apparent that the failure of the maximum STLI to predict LBP will also apply to these equations.

Recommendations

Attention should be paid to developing better methods of assessing risk of LBP from manual handling with a focus on creating better ways of combining multiple risk factors and of combining exposures to multiple tasks.

Further analysis should be carried out on the data collected by this study, in particular to test the ability of the HSE MAC tool to predict LBP.

1 BACKGROUND

1.1 IDENTIFICATION AND CONTROL OF HAZARDOUS MANUAL HANDLING OPERATIONS

Low back pain (LBP) is widespread in both the general population and the working population. There is evidence that manual handling increases the risks of LBP. As a result, a considerable body of scientific literature exists that attempts to identify risk factors. Due to the high costs associated with work loss and treatment, a variety of methods have been suggested to control the risks in the workplace and hence to reduce the incidence and prevalence of LBP and other musculoskeletal disorders (MSDs). The legal framework in the UK, the Manual Handling Operations Regulations 1992 (Health and Safety Executive, 2004) requires duty-holders to use an ergonomic approach to identify risk factors and to take appropriate action to modify the risk factors and hence reduce the risk. This approach has avoided specifying any kind of weight limits or creating precise definitions of levels of risk, though the MAC tool (Health and Safety Executive and Health and Safety Laboratory, 2003) has sought to give guidance on risk levels through a traffic light system.

Measuring exposure to musculoskeletal risk factors is both conceptually and practically complex and a wide variety of methods of assessing risk from manual handling have been developed and described in the scientific literature.

A widespread approach in the past has been to consider evidence about manual handling risks from four scientific viewpoints – the epidemiological, biomechanical, physiological, and psychophysical. In 1981 in the USA an *ad hoc* NIOSH (National Institute of Occupational Safety and Health) committee of experts summarised the research under these four approaches and used it to synthesise an equation to predict safe lifting limits from a number of parameters of a defined type of lifting task (NIOSH, 1981). This became known as the NIOSH Lifting Equation.

A number of reports were published in 1991 (NIOSH, 1991) summarising how the scientific literature had developed after 1981 and these underpinned a revised version of the equation – "The Revised 1991 NIOSH Lifting Equation" (Waters *et al.,* 1993; Waters *et al.,* 1994). The 1991 equation predicted a "Recommended Weight Limit" (RWL) from the spatial and temporal parameters of the task and, as a measure of risk, calculated the ratio of the actual load being lifted to the RWL to give a "Lifting Index" (LI). Waters *et al.* (1993) stated that it was believed by the committee that had created the equation that designing tasks to have LIs of less than 1.0 would protect 90% of the working population from an increased risk of LBP from lifting. They clearly admitted that the shape of the risk function was unknown but stated that the majority of the committee believed that the risk increased substantially above a LI of 3.0.

Both the 1981 and 1991 NIOSH equations were widely disseminated in the USA and internationally (Ayoub and Mital, 1989; Pheasant, 1991; Liles and Mahajan, 1985; Konz, 1982; Freivalds, 1987; Chaffin, 1987; Declercq and Lund, 1993; Steinbrecher, 1994; Auguston, 1995; Waters and Putz-Anderson, 1999; Waters and Putz-Anderson, 1997). A number of studies have sought to examine the basis, accuracy and applicability of the equations (Leamon, 1994a; Leamon, 1994b; Hidalgo and Genaidy, 1995; Potvin, 1997; Jager and Luttmann, 1999; Marklin and Wilzbacher, 1999). European and international standards have been based upon derivatives of the 1991 NIOSH equation (BS EN 1005-2, 2003; ISO 11228-1, 2003). A number of other modifications / extensions of the 1991 equation have also been published (Stambough *et al.,* 1995; Hidalgo *et al.,* 1997; Shoaf *et al.,* 1997; Maiti and Ray, 2004).

Dempsey *et al.* (2002) reported the preliminary results of a prospective study carried out in the USA by Liberty Mutual that sought to examine the relationship between the LI and the risk of lost time due to LBP (LBP). They pointed out that the limited evidence available about the shape of the risk function suggests that the relationship between LI and risk to the low back is non-linear.

1.2 PURPOSE OF THIS STUDY

The purpose of this study was to replicate the Liberty Mutual study in the United Kingdom by carrying out a prospective evaluation of the ability of the NIOSH lifting equations to predict loss of time from work due to LBP. In addition, it was desired to evaluate the derivative equations that have been published in the international and European standards.

2 LITERATURE REVIEW – RISK ASSESSMENT IN MANUAL HANDLING

2.1 RISK ASSESSMENT CONCEPTS IN MANUAL HANDLING

Straker (1997) provides an overview of how the concepts of risk assessment have been applied to manual handling. Key terms and their formal definitions are discussed below. It is necessary to be aware that some terms such as “hazard” and “risk” are often used interchangeably, especially in everyday use (Health and Safety Executive, 2001) and sometimes the term “risk” can be used to mean any of “consequence” or “harm” or “exposure” (Straker, 1997).

2.1.1 Hazard

This is a potential cause of harm. Thus, manual handling itself is a hazard.

- A *zero* hazard is a hazard where any exposure can cause harm.
- A *threshold* hazard is a hazard where harm can only occur above a threshold exposure. Below the threshold, exposure may result in benefit.

Manual handling can therefore be seen as a threshold hazard, with some levels of manual handling being beneficial to health.

2.1.2 Risk

This is the probability of a negative outcome, i.e., of harm occurring.

2.1.3 Consequence or harm

This is an undesirable outcome resulting from exposure to a hazard. It has three components:

- Type, e.g., decrements in health, satisfaction or performance;
- Severity, i.e., the amount of harm or degree of incapacity;
- Duration, i.e., the persistence of the harm and whether it is temporary or permanent.

2.1.4 Exposure

This can mean any of:

- The number or proportion of exposed individuals;
- The number of hazards an individual is exposed to; or
- The amount of hazard an individual is exposed to, as measured by the frequency, duration and magnitude.

2.1.5 Acceptable risk

This is an ambiguous notion and situation / context dependent. The risk of suffering harm is an inescapable aspect of living (Health and Safety Executive, 2001). The legal system in the UK demands that risk be reduced “as far as is reasonably practicable” and the legal test of this (Health and Safety Executive, 2001; 2004) is whether the cost of a further reduction of risk would be “grossly disproportionate” to the benefit that would accrue.

2.1.6 Permissible risk

A level of risk, below a limit or standard, that has expert or community support.

2.2 EXISTING RISK ASSESSMENT METHODS IN MANUAL HANDLING

In addition to the 1981 (NIOSH, 1981) and 1991 NIOSH lifting equations (Waters *et al.,* 1994), a number of methods exist either for determining safe limits for manual handling of loads or for assessing the risk of low back injury due to manual handling. David (2005) has provided an overview. Most methods rely on snapshot assessments of single postures, often those believed to be hazardous or problematic. Time-sampling and weighting of measurements to reflect exposure are possible but time-consuming and offer further difficulties in interpretation.

The other available methods include:

- The Quick Exposure Check (QEC) (David *et al.,* 2008; Brown and Li, 2003; Li and Buckle, 1999);
- Rapid Entire Body Assessment (REBA) (Hignett and McAtamney, 2000; Kee and Karwowski, 2007);
- OWAS (Karhu *et al.,* 1977; Karhu *et al.,* 1981; Kivi and Mattila, 1991; Vedder, 1998);
- The Manual handling Assessment Charts (MAC) tool (Health and Safety Executive and Health and Safety Laboratory, 2003; Monnington *et al.,* 2002; Monnington *et al.*, 2003);
- The Key Indicator Method (KIM) (Steinberg *et al.,* 2006).

Pinder (2002a) benchmarked the QEC, REBA, OWAS and the 1991 NIOSH equation against the MAC and explored the implicit mathematical models underlying them. He showed that there were traceable links between the different methods but that none had been formally validated as predictors of risk of injury or sickness absence. He also showed that there were no systematic differences in how the different methods ranked the levels of risk of the tasks studied but the way that the severity of tasks was ranked was random. He concluded that the tools appear to assess risk in different ways and therefore cannot easily be compared. He also noted a need for risk assessment tools to distinguish between risk to the low back and risks to the upper limbs, in contrast to tools such as REBA and the QEC, which create overall scores from a mixture of risk factors specific to the upper limb and specific to the low back.

2.3 COMPARISON OF THE VARIOUS LIFTING EQUATIONS

2.3.1 The 1981 NIOSH equation

The 1981 NIOSH equation (NIOSH, 1981) calculates an "Action Limit" (AL) using a maximum load and a set of four multipliers. It has the following form:

$$(1) \quad AL = LC \times HM \times VM \times DM \times FM$$

A "Maximum Permissible Limit" (MPL) is also calculated as follows:

$$(2) \quad MPL = 3 \times AL$$

The "Load Constant" (LC) is reduced by the multipliers which are all less than or equal to 1.0, and so act as discounting factors. The multipliers are defined as being equal to 1.0 under ideal lifting conditions. Table 1 lists the factors and multipliers, using the metric form of the equation, but with distances being expressed in mm rather than cm.

Table 1 The factors in the 1981 NIOSH equation

Variable	*Description*	*Multiplier*	*Function*	*Ideal value*
L	Load constant	LC	LC = 40 kg	40 kg
H	Horizontal distance from mid-ankle to the mid point of the hands	HM	HM = 150/H	150 mm
V	Vertical height of the (start) of the lift	VM	$VM = 1 - 0.0004 \times \lvert V - 750 \rvert$	750 mm
D	Vertical distance the load travels through	DM	DM = 0.7 + 75 / D	≤ 250 mm
F and Fmax	Frequency of lift and maximum lifting frequency. Fmax depends on the duration of lifting and the value of V.	FM	FM = 1 − F / Fmax	≤ 0.2 lifts per minute; duration ≤ 1 hour

The 1981 equation was designed for use with a restricted subset of manual lifting tasks; specifically smooth two-handed symmetric lifting in front of the body, with unrestrained postures, good hand-object couplings and favourable environmental conditions.

The AL was linked to the capacity of a 25th percentile female worker and a 1st percentile male worker. Only 25% of workers are weaker than an 25th percentile individual and only 1% of workers are weaker than a 1st percentile individual so these represent small females and very small males. The MPL was linked to the capacity of a 99th percentile female worker and a 75th percentile male worker, representing very large females and large males. The guide to the 1981 equation (NIOSH, 1981) recommended that tasks above the MPL should be viewed as unacceptable and engineering controls implemented. For tasks between the MPL and the AL, the guide recommended administrative or engineering controls. The guide viewed tasks below the AL as representing nominal risk to most industrial workforces so constituting “Acceptable Lifting Conditions”.

2.3.2 The 1991 NIOSH equation

The 1991 equation (Waters *et al.,* 1993; Waters *et al.,* 1994) is a modification of the 1981 equation. While keeping the basic equation where a maximum load is multiplied by discounting factors, instead of calculating an AL and an MPL, it calculates a single “Recommended Weight Limit” (RWL). The factors are defined in Table 2, again in SI units, with distances in mm, and the equation has the following form:

(3) $RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$

A different approach was therefore taken to determining the risk from the task. Instead of having two limits linked to the capacity of percentiles of the population, the ratio of the actual load to the RWL is calculated, giving a “Lifting Index” (LI).

(4) $LI = Load / RWL$

Such an approach is an obvious means of considering the severity of a task, and had been used with the 1981 equation by Pinder and Pheasant (1988).

As the RWL and the LC both have dimensions of Mass, and units of kilograms in the SI system, all of the multipliers and the LI are dimensionless and do not have units.

Table 2 The factors in the 1991 NIOSH equation

Variable	*Description*	*Multiplier*	*Function*	*Ideal value*
L	Load constant	LC	LC = 23 kg	23 kg
H	Horizontal distance from mid-ankle to the mid point of the hands	HM	HM = 250 / H	250 mm
V	Vertical height of the start or finish of the lift	VM	VM = 1 − 0.0003 × |V − 750|	750 mm
D	Vertical distance the load travels through	DM	DM = 0.82 + 45 / D	≤ 250 mm
A	Angle of asymmetry	AM	AM = 1 − 0.0032 × A	0°
C	Quality of hand-object coupling / grip on the load	CM	CM is found from a look up table and depends on the value of V.	"Good" coupling
F	Frequency of lift	FM	FM is found from a look-up table and depends on the frequency of lift, duration of lifting, and the value of V.	≤ 0.2 lifts per minute; duration ≤ 1 hour

The other changes from the 1981 equation were that two multipliers were added to permit the analysis of asymmetric tasks and those with less than perfect hand-object couplings. At the same time, the LC and the four multipliers derived from the 1981 equation were modified in the light of the increased scientific knowledge gained in the intervening period. The most visible change was that the LC was reduced to 23 kg, but the minimum value of the hand distance from the low back was increased to 250 mm to compensate for this, resulting in the LC × HM values being effectively identical in the 1981 and 1991 equations.

2.3.3 Origin of the use of multiplicative equations

Drury and Pfeil (1975) appears to be the paper that sets out the thinking that led to the use of a multiplicative model. In fact, Drury was a member of both of the *ad hoc* committees that were responsible for developing both the 1981 and 1991 NIOSH equations. Drury and Pfeil (1975) proposed a multiplicative model to predict either lifting performance or maximum recommended weights from a large number of task variables. They argued that in many instances similar ratios are obtained for performance in various conditions, making a multiplicative model appropriate. They carried out an experiment to test a model predicting maximum acceptable weight of lift with a number of multipliers. The correlation they obtained between predicted and measured weights was very high ($r = 0.936$) but only five subjects took part. This approach assumes a perfect relationship between maximum acceptable weight and risk of injury. This appears to have never been tested.

2.3.4 Assumptions in the NIOSH equations

Karwowski (1992) listed the following assumptions as underlying the use of multiplicative models in the NIOSH equations:

- All lifting factors are independent of each other;
- The effects of multipliers are synergistic,
- Each factor contributes about the same amount of risk to the overall risk of low-back injury due to a given lifting task.

These assumptions would be invalid if there were interactions between different lifting factors, i.e. they were not independent.

2.3.5 "Behaviour" of the 1991 NIOSH equation

A computer simulation (Karwowski and Gaddie, 1995) looked at the distribution of RWL values using probability distributions of the risk factors chosen to be representative of the real industrial workplace. This produced a distribution of RWL values with a mean of 7.2 kg (Standard Deviation (SD) 2.09 kg), with a range from 0 kg to 17.2 kg. Of the RWLs obtained, less than 0.5% were greater than 12.5 kg. Split by task duration, this 0.5% threshold, which they considered useful for immediate risk assessment of manual lifting tasks, was 13.0 kg for 1 hour tasks, 12.5 kg for 2 hour tasks, and 10.5 kg for 8 hour tasks. They concluded that it was reasonable to expect that using the LI of 1.0 as a threshold would require redesign of tasks above these thresholds. In the context of the UK regulations and HSE guidance (Health and Safety Executive, 2004), it is worth noting that the maximum filter figure for determining when a detailed risk assessment is needed is 25 kg, which is almost twice the maximum threshold figure here. The assumptions underlying the choice of distributions used in the simulation do not involve risk of injury, unlike the HSE filter, and the cut-off point of 0.5% is selected in a different manner. The precise relationship between the two methods of threshold setting is therefore complex and not clearly defined.

2.4 OTHER LIFTING EQUATIONS

2.4.1 The ISO equation

The lifting equation published in ISO standard 11228 (ISO 11228-1, 2003) is almost identical to the 1991 NIOSH equation except that it uses different symbols:

(5) $m \leq m_c \times k_d \times k_h \times k_s \times k_a \times k_f \times k_g$

As with the 1991 NIOSH equation, the multipliers are dimensionless.

The first main difference is that the LC is replaced by a "mass constant", m_C, that depends on the population under consideration. m_C is 25 kg for the "Adult working population" and 15 kg for the "General working population, including the young and old". "Young" and "old" are not defined. It is also stated that, "In order to lower the risk for people at work, particularly those with less physical capacity, the recommended limit for mass should not exceed 15 kg." The maximum acceptable load for an adult population is therefore 25 kg in ideal conditions rather than the 23 kg in the 1991 NIOSH equation. The logic for changing this to 25 kg is not stated.

The second main difference is that there is no definition of a "lifting index" or "risk index". Instead, the actual mass has to be less than the reference constant, m_C, which is treated as an absolute threshold. For convenience, the ratio of actual load to m_C has been described as a "Lifting Index".

2.4.2 The EN equation

The lifting equation published in Part 2 of the European Standard EN 1005 (BS EN 1005-2, 2003) is also a modification of the 1991 NIOSH equation. The BS in the citation indicates that it has been adopted as a British Standard. As with the ISO equation, the symbols are slightly different from the NIOSH symbols. Two "Recommended Mass Limits", R_{ML2} and R_{ML}, are defined. R_{ML2} is equivalent to the 1991 NIOSH equation RWL.

(6) $R_{ML2} = M_{ref} \times V_M \times D_M \times H_M \times A_M \times C_M \times F_M$

Though the multipliers are the same as the six multipliers in the 1991 NIOSH equation, two of them have slightly different definitions:

- The Vertical Multiplier treats all positions below ground level as being at ground level, rather than out of range.
- The Coupling Multiplier does not distinguish between lifts below knuckle height and lifts above knuckle height, but treats the quality of the coupling as solely a function of the nature of the object(s) being handled.

There is a risk index, R_I, which is defined as:

$$(7) \quad R_I = \text{Actual mass} / R_{ML2}$$

R_{ML} is designed to be a more comprehensive evaluation that adds three more multipliers. These are to allow analysis of one-handed tasks (O_M), team handling in pairs (P_M), and carrying out additional tasks (A_T).

$$(8) \quad R_{ML} = M_{ref} \times V_M \times D_M \times H_M \times A_M \times C_M \times F_M \times O_M \times P_M \times A_T$$

When R_{ML2} is calculated the risk index is defined as:

$$(9) \quad R_I = \text{actual mass} / R_{ML}$$

As with the 1991 NIOSH equation, the multipliers and the risk index are dimensionless. The defined interpretation of R_I is set out in Table 3.

Table 3 Interpretation of R_I values calculated using BS EN 1005-2

R_I value	***Interpretation***	***Colour code***
$R_I \leq 0.85$	The risk may be regarded as tolerable	Green
$0.85 < R_I < 1.0$	Significant risk exists	Yellow
$1.0 \leq R_I$	Redesign is necessary	Red

The NIOSH LC is replaced by a reference mass, M_{ref} that, as with the ISO equation, depends on the population under consideration. M_{ref} is 25 kg for the "Adult working population" and 15 kg for the "General working population, including the young and old". As with the ISO equation, neither "young" nor "old" are defined, nor is the logic of changing the 23 kg NIOSH LC to 25 kg stated. The reason for creating the "Yellow" zone is not explained.

2.4.3 The MAC tool lifting chart

The MAC tool developed by HSE and HSL has the following equation underlying the lifting chart (Pinder, 2002a):

$$(10) \quad R_{TASK} = R_{LF} + R_H + R_{LZ} + R_A + R_P + R_G + R_F + R_E + R_U + e$$

This equation has a different conceptual basis and a hence different mathematical form. Instead of attempting to determine a weight limit for a particular set of lift parameters it attempts to estimate actual risk of injury to the person carrying out the manual handling operation. Therefore, each R term is an estimate of risk of injury from one risk factor and an estimate of the total risk is obtained by summing them. The equation includes R_U, a term for unattributed risk and an error term, e. The unattributed risk term acknowledges that there are risk factors that are not included in the MAC; the error term acknowledges that there are inevitable errors in the measurement of risk factors and in the assignment of risk scores to the levels of the risk factors.

2.5 COMPARISON OF LIFTING EQUATIONS

2.5.1 Comparison of parameters

The terms in the different equations are compared in Table 4. The stated assumptions and limitations of the different equations are compared in Table 5.

Table 4 Comparison of the terms in the different lifting equations

	1981 NIOSH	*1991 NIOSH*	*ISO 11228-1*	*BS EN 1005-2*	*MAC*
Load / mass factor	LC = 40 kg	LC = 40 kg	m_c = 25 kg (adult working population) or 15 kg (general working population)	M_{ref} = 25 kg (adult working population) or 15 kg (general working population)	R_{LF}
Horizontal location factor	HM	HM	k_d	H_M	R_H
Vertical location factor	VM	VM	k_h	V_M	R_{LZ}
Distance lifted factor	DM	DM	k_s	D_M	—
Asymmetry of task factor	—	AM	k_a	A_M	R_A
Coupling / grip factor	—	CM	k_g	C_M	R_G
Frequency of handling factor	FM	FM	k_f	F_M	R_{LF}
One handed factor	—	—	—	O_M	—
Two-person factor	—	—	—	P_M	Separate chart for team lifting
Additional task factor (e.g. carrying)	—	—	—	A_T	Separate chart for carrying
Postural constraints	—	—	—	—	R_P
Floor surface	—	—	—	—	R_F
Other environmental factors	—	—	—	—	R_E
Recommended / action limit(s)	AL and MPL	RWL	M	R_{ML2} or R_{ML}	Amber or Red scores
Lifting / Risk index	—	LI = Load / RWL	None defined	R_I = Load / R_{ML2} or R_I = Load / R_{ML}	Total score
Index thresholds		LI = 1.0 LI = 3.0	M = m_C	R_I = 0.85 R_I = 1.0	

Table 5 Stated assumptions and limitations of the NIOSH, EN and ISO equations

	NIOSH 1981	***NIOSH 1991***	***EN Method 1***	***EN Method 2***	***EN Method 3***	***ISO Step 1***	***ISO Step 2***	***ISO Step 3***	***ISO Step 4***	***ISO Step 5***
Non-lifting / lowering, manual handling	Minimal	Minimal	Minimal	Minimal	Additional MH tasks permitted	Minimal	Minimal			Carrying permitted
"Unexpected events"				Not permitted						
Climatic conditions	Favourable ambient environment	19 – 26 °C, 35 - 50% RH	19 – 26 °C, 30 - 70% RH, air velocity < 0.2 m/s	19 – 26 °C, 30 - 70% RH, air velocity < 0.2 m/s	19 – 26 °C, 30 - 70% RH, air velocity < 0.2 m/s	Favourable environmental conditions / moderate ambient thermal environment	Favourable environmental conditions / moderate ambient thermal environment			
Number of hands			Two	Two	Two	Two	One or two	Two	Two	
Seated lifting				Not permitted						
Kneeling lifting				Not permitted						
Postural constraints due to workspaces	None	None	None	None	None	None	None			
Stability of loads				Stable only	Stable or unstable	Stable or unstable	Stable or unstable			
Lifting speed				< 0.75 m/s						
Wheelbarrow or shovel handling		Not permitted								
Floor / foot coefficient of friction		> 0.4.	Good coupling	Good coupling	Good coupling	Good coupling	Good coupling			
Both lifting and lowering tasks?	Lifting only	Both				Both	Both	Both	Both	Both

	NIOSH 1981	*NIOSH 1991*	*EN Method 1*	*EN Method 2*	*EN Method 3*	*ISO Step 1*	*ISO Step 2*	*ISO Step 3*	*ISO Step 4*	*ISO Step 5*
Max lifting duration	8 hours	8 hours	Maximum work shift of 8 hours	Maximum work shift of 8 hours	Maximum work shift of 8 hours		2 hours	8 hours		
Maximum lifts per minute		18	15	5	12	15	Less than one lift every five minutes	15	15	
Smoothness of lift			Smooth		Smooth	Smooth	Smooth			
Object characteristics			Not very hot, cold or contaminated	Not very hot, cold or contaminated	Not very hot, cold or contaminated	Not hot, cold or contaminated	Not hot, cold or contaminated			
Number of handlers					One	One	Up to two	One	One	
Quality of hand / load couplings	Good couplings only	Poor couplings permitted	Good couplings only	Poor couplings permitted	Poor couplings permitted	Firm grip / good coupling	Firm grip / good coupling			
Trunk rotation permitted	No	Yes	No	Yes	Yes	No	No			
Maximum horizontal distance of load grip	Up to 80 cm	Up to 63 cm from mid ankle	Close to the body	Up to 63 cm from mid ankle	Up to 63 cm from mid ankle	< 0.25 m from low back	< 0.25 m from low back			
Height of load						KH to KH + 0.25 m	KH to KH + 0.25 m			
Vertical displacement of load						< 0.25 m	< 0.25 m			
Lift zone						Hip - shoulder	Hip - shoulder			
Trunk posture								Upright	Upright	
Object width (sagittal plane)		Less than 75 cm								

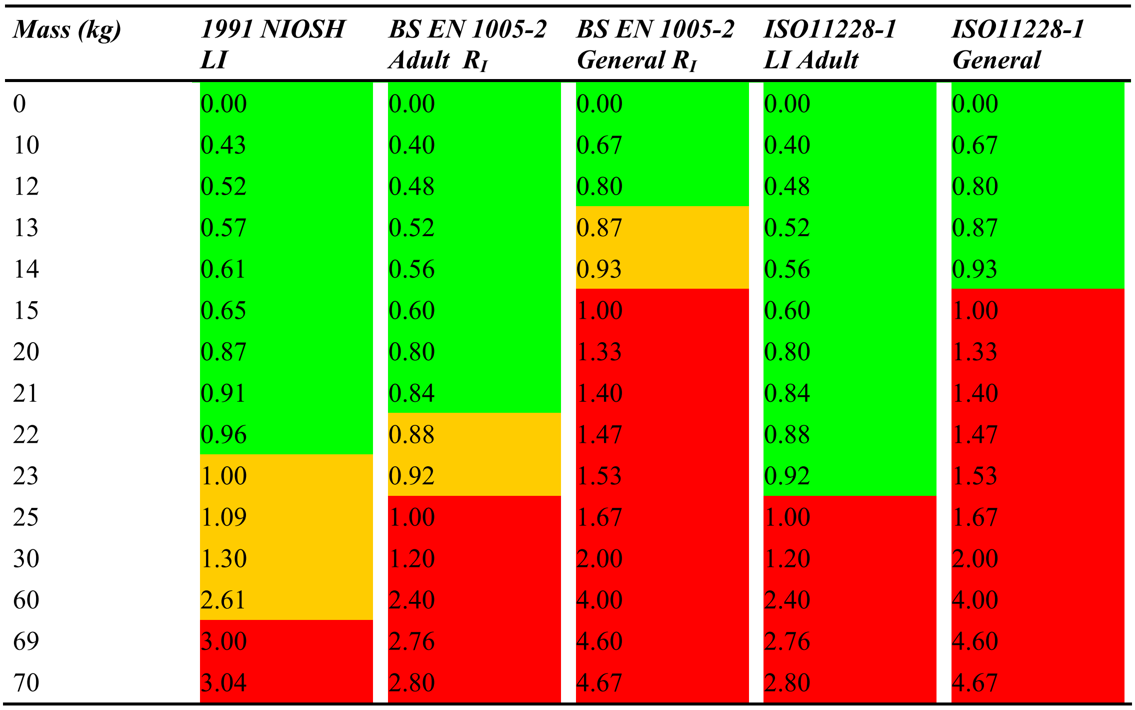
2.5.2 Comparison of risk thresholds

For the 1981 NIOSH equation, the zone between LI = 1 and LI = 3 is where administrative or engineering controls are required. Above LI = 3 (the MPL) administrative controls are not considered adequate and engineering controls are the only acceptable solution. The 1991 equation abandoned this explicit distinction, but the discussion in Sections 1.4.2 and 1.4.3 of the Applications Manual for the 1991 NIOSH equation (Waters *et al.,* 1994) makes clear that there were differences of perspective among the *ad hoc* committee responsible for the equation:

> *"In other words, as the magnitude of the LI increases, (1) the level of the risk for a given worker would be increased, and (2) a greater percentage of the workforce is likely to be at risk for developing lifting-related low back pain. The shape of the risk function, however, is not known."*
>
> *"From the NIOSH perspective, it is likely that lifting tasks with a LI > 1.0 pose an increased risk for lifting-related low back pain for some fraction of the workforce (Waters et al., 1993). Hence, the goal should be to design all lifting jobs to achieve a LI of 1.0 or less. Some experts believe, however, that worker selection criteria may be used to identify workers who can perform potentially stressful lifting tasks (i.e., lifting tasks that would exceed a LI of 1.0) without significantly increasing their risk of work-related injury (Chaffin and Andersson, 1984; Ayoub and Mital, 1989). Those selection criteria, however, must be based on research studies, empirical observations, or theoretical considerations that include job-related strength testing and/or aerobic capacity testing. Nonetheless, these experts agree that nearly all workers will be at an increased risk of a work-related injury when performing highly stressful lifting tasks (i.e., lifting tasks that would exceed a LI of 3.0). Also, informal or natural selection of workers may occur in many jobs that require repetitive lifting tasks. According to some experts, this may result in a unique workforce that may be able to work above a lifting index of 1.0, at least in theory, without substantially increasing their risk of low back injuries above the baseline rate of injury."*

In order to take account of these different perspectives, and to allow comparison with the ISO and EN approaches, the risk thresholds for the multiplicative equations are compared in Table 6 using Red, Yellow/Amber and Green colour coding. The LI = 3 value is used as an upper risk threshold for the 1991 NIOSH equation, with the LI > 3 zone assigned to the "Red" zone and the zone between LI = 1 and LI = 3 assigned to a "Yellow" zone.

Table 6 Comparison of risk thresholds



Mass (kg)	*1991 NIOSH LI*	*BS EN 1005-2 Adult R_I*	*BS EN 1005-2 General R_I*	*ISO11228-1 LI Adult*	*ISO11228-1 General*
0	0.00	0.00	0.00	0.00	0.00
10	0.43	0.40	0.67	0.40	0.67
12	0.52	0.48	0.80	0.48	0.80
13	0.57	0.52	0.87	0.52	0.87
14	0.61	0.56	0.93	0.56	0.93
15	0.65	0.60	1.00	0.60	1.00
20	0.87	0.80	1.33	0.80	1.33
21	0.91	0.84	1.40	0.84	1.40
22	0.96	0.88	1.47	0.88	1.47
23	1.00	0.92	1.53	0.92	1.53
25	1.09	1.00	1.67	1.00	1.67
30	1.30	1.20	2.00	1.20	2.00
60	2.61	2.40	4.00	2.40	4.00
69	3.00	2.76	4.60	2.76	4.60
70	3.04	2.80	4.67	2.80	4.67

2.6 THE COMPOSITE LIFTING INDEX

The Composite Lifting Index (CLI) (Waters *et al.,* 1994) is an extension of the 1991 NIOSH LI that allows the evaluation of "multi-task" jobs involving multiple lifting tasks with different parameters. Typical examples are palletising or depalletising where the position of the lift changes as the pallet is built up or emptied, or assembly operations where a number of components are handled as they are put together and the complete assembly is then handled at the end.

Such jobs can be divided into a set of tasks that can be evaluated separately, but the overall demands of the job must be evaluated by considering all tasks together. This is particularly important, as the overall frequency of handling is the sum of the frequencies of handling of the individual tasks.

The procedure for calculating the CLI is set out in Table 7. The basis of the calculation is finding the largest Single Task Lifting Index (STLI) within the job. An increment is then added for the change in lifting index (ΔLI) caused by adding each additional task to the overall job.

The purpose of the CLI approach is to separate considerations of capacity based estimates of strength and estimates of metabolic demand (Waters, 1991). This is done by calculating a Frequency Independent Lifting Index (FILI) and then calculating the STLI and CLI by taking the effect of frequency into account. The FILI provides an estimate of the biomechanical risk of each lifting task; the STLI provides an estimate of risk that takes into account the combined biomechanical and physiological demands of a task. The CLI reflect the combined demands of the whole job. The ΔLI value is calculated using the FILI value and the change in the FM caused by adding the additional task. This means that the base value of the CLI is based on the mean weight of the worst task but the increments are based on the maximum weight of the additional tasks.

Table 7 Steps for calculating CLI

Step	***Description***
1	Compute the Frequency Independent Recommended Weight Limit (FIRWL) for each task by setting the value of FM to 1.0.
2	Compute the Single-Task Recommended Weight Limit (STRWL) for each task by multiplying the FIRWL by the appropriate value of FM for each task.
3	Compute the Frequency-Independent Lifting Index (FILI) for each task by dividing the maximum load weight for that task by the FIRWL.
4	Compute the Single-Task Lifting Index (STLI) for each task by dividing the mean load weight by the STRWL.
5	Renumber the tasks in the order of decreasing STLI.
6	Find the frequency of the first task (greatest STLI) and the associated value of FM.
7	Add one task at a time, calculating the cumulative frequency of handling and the associated value of FM.
8	Calculate ΔLI for each additional task by dividing the FILI for the task by the change in FM due to the increase in frequency of handling. So, for the second task: $\Delta LI_2 = FILI_2 \times (1 / FM_{1,2} - 1 / FM_1)$ where $FM_{1,2}$ = frequency multiplier for the combined frequency of tasks 1 and 2, and FM_1 = frequency multiplier for task 1.
9	Add the ΔLI values to $STLI_1$ to give the CLI: $CLI = STLI_1 + \Sigma \Delta LI$

Testing the CLI equation reveals that for infrequent lifting, where the total frequency does not exceed 0.2 lifts per minute, (one lift every 5 minutes, 12 lifts per hour) the CLI is equal to the STLImax value. Table 8 demonstrates this by comparing the example given by Waters *et al.* (1994) (p47) with the same three tasks each performed at a rate of 0.1 lifts per minute.

Table 8 CLI example from P47 of Waters *et al.* (2004)

Task number	***1***	***2***	***3***	***1***	***2***	***3***
Load weight (kg)	30	20	10	30	20	10
F (lifts per minute)	1	2	4	0.1	0.1	0.1
FIRWL (kg)	20	20	15	20	20	15
FM	0.94	0.91	0.84	1.00	1.00	1.00
STRWL (kg)	18.8	18.2	12.6	20	20	15
FILI	1.5	1.0	0.667	1.5	1.0	0.667
STLI	1.6	1.1	0.8	1.5	1.0	0.667
Task rank	1	2	3	1	2	3
STLI reordered	1.6	1.1	0.8	1.5	1.0	0.667
Previous task number	1	2	3	1	2	3
F reordered	1	2	4	0.1	0.1	0.1
Fsum (lifts per minute)	1	3	7	0.1	0.2	0.3
FM for ΔLI	0.94	0.88	0.70	1.00	1.00	0.99
FILI reordered	1.5	1.0	0.667	1.5	1.0	0.667
ΔLI	1.60	0.07	0.19	1.50	0.00	0.01
CLI	1.60	1.67	1.86	1.50	1.50	1.51

2.7 THE SEQUENTIAL LIFTING INDEX

NIOSH authors (Waters *et al.,* 2007) have recently proposed a “Sequential Lifting Index (SLI) analogous to the CLI to allow the analysis of exposure where workers rotate between jobs with different physical demands. They proposed this because their previous work (Waters *et al.,* 1999) had forced them to assign as an exposure value the greatest LI value that occurred during the shift. They considered that this tended to result in overestimation of the LI, biasing the risk estimate towards the null.

They consider that

- The order of exposure of varying tasks needs to be considered when calculating the RWL.
- The relative time exposures of the different tasks need to be considered when calculating the RWL.

They used three assumptions:

- The physiological demand for a sequence of “rotation slots” / “lifting elements” performed over a shift will be different to the demand of a single slot / element performed over the duration of the shift.
- The difference in demand will be a function of the duration of the time spent on each element.
- The physiological demand will be function of the sequence of activities and the recovery periods built into them.

The steps for the SLI process are set out in Table 9:

Table 9 Steps for calculating SLI

Step	***Description***
Step 1	Document the work pattern or rotation pattern of manual handling tasks, recovery periods and meal breaks. This needs to be broken down into periods of each category of task. The example they give has manual handling task categories A and B, a light task C and a meal break R with the following pattern of 1 hour periods: AABRAABCC
Step 2	Calculate the LI or CLI for each task period of each manual handling task category
Step 3	Calculate the maximum LI (LImax) for each manual handling task category using values of FM based on total duration of handling for the longest continuous lifting period.
Step 4	Calculate the time fraction (TF) of 240 minutes of the total duration of each manual handling task category. The value of 240 minutes is used because in most workplaces no continuous lifting task takes place for longer than this without a break.
Step 5	Reorder tasks by their LImax values. The task with the highest LImax becomes task 1, so its LImax and LI are referred to as LImax_1 and LI_1.
Step 6	Calculate the SLI: $\text{SLI} = \text{LI}_1 + (\text{LImax}_1 - \text{LI}_1) \times \Sigma\ (\text{LImax}_i \times \text{TF}_i) / \text{LImax}_1$

The SLI equation is designed so that if there are sufficient recovery periods to ensure that each period of handling is within the Short Duration (<1 hr) category then the SLI is equal to the greatest of LImax or CLImax. This is because LImax_1 becomes equal to LI_1, cancelling out the $(\text{LImax}_1 - \text{LI}_1) \times \Sigma\ (\text{LImax}_i \times \text{TF}_i) / \text{LImax}_1$ term.

They note that the SLI appears to be sensitive to variations in the sequence of work tasks across the work shift. This appears to be a function of the provision of rest breaks and the fact that any continuous work period of more than two hours will use the 8 hour values of FM. Thus, two hours lifting followed by four hours rest followed by two hours lifting will have a smaller SLI than four hours lifting followed by four hours rest. It is noticeable that some of their example combinations (Table 10) have identical SLI values:

Table 10 Example task sequences and SLI values (Waters et al., 2007)

Sequence	*SLI*
BABA	4.34
ABAB	4.34
BBAA	4.82
AABB	4.82
AAAC	5.89
AAAB	5.89
AAAA	5.89

Tasks A and B involve manual handling; Task C does not involve manual handling; each letter represents 55 minutes of work.

2.8 OTHER LIFTING EQUATIONS

2.8.1 The “Comprehensive Lifting model”

Stambough *et al.* (1995) sought to create a comprehensive mathematical lifting model that took into account both task factors, (as done by the NIOSH equations) and personal factors. They chose a multiplicative model as used by NIOSH, and, earlier, by Drury and Pfeil (1975).

Their model has the following form:

$$(11)\quad LC = W_B \times H \times V \times D \times F \times TD \times T \times C \times HS \times AG \times BW$$

Here LC is the lifting capacity and W_B is the “base weight” or the maximum load acceptable to different percentages of the population. H and V are horizontal and vertical location multipliers; D is a vertical travel distance multiplier and F is a frequency multiplier. TD is a task duration multiplier, T is a trunk asymmetry multiplier, C is a coupling multiplier, and HS is a heat stress multiplier. AG and BW are age group and body weight multipliers. All multipliers except BW fall in the range of 0 and 1.0, and so act as discounting factors. Psychophysical data (Ciriello *et al.,* 1993; Snook, 1978; Snook and Ciriello, 1991; Ayoub *et al.,* 1978; Mital, 1983; Mital and Fard, 1986; Mital *et al.*, 1993; Asfour *et al.,* 1984; Garg and Badger, 1986; Hafez, 1984), were used to determine the functions used to convert task measurements to multipliers. Physiological data from Asfour *et al.* (1991), biomechanical data from Genaidy *et al.* (1993) and Tichauer (1978) were used to modify the effects of the psychophysically derived multipliers.

Their comparison with the Drury and Pfeil (1975) model and the 1981 and 1991 NIOSH equations showed that Drury and Pfeil predicted much higher capacities, due to using solely psychophysical criteria. The NIOSH AL and RWL were consistently two to three times higher except for high frequencies of lift. They attributed this to different physiological criteria and to lower base weights in their study. They did not report any validation of the model in the paper.

2.8.2 “General lifting equations”

Abdallah *et al.* (2005) proposed a “general lifting equation based on “the laws of mechanics and physics”. The underlying concept was that it should be based on the mechanical work required against gravity and against friction. They also incorporated “stress coefficients” to account for aspects of task difficulty not captured by the mechanical work parameters. In fact their use of “work against friction” was notional as they “assumed that there is imaginary mechanical work against frictional forces” when developing multipliers to take account of factors such as horizontal distance of the load. Genaidy *et al.* (2006) developed this approach further by applying it to combinations of tasks, such as lifting, pushing, pulling etc. The theoretical problems with this approach, where considerations of lumbar stress and psychophysical acceptability are replaced by “imaginary work” which is then modified by stress coefficients, mean that it will not be considered further in this report.

2.8.3 Limits based on physiological criteria

A different approach (Maiti and Ray, 2004) created a multiplicative equation to predict working heart rate and hence oxygen consumption, from the height of the lift, lifting frequency (F) and load weight (W). The maximum load limit for Indian adult women workers was then estimated from this. Their equation for Working Heart Rate (WHR) was of the form:

$$(12) \quad WHR = C \times FM \times WM \times DM$$

where C is a constant, FM is a Frequency Multiplier, WM is a Weight Multiplier that depends on both W and F, and DM is a vertical travel Distance Multiplier.

While the use of a multiplicative equation is similar in concept to the equation for the NIOSH RWL, the differences in the two approaches are large. It is possible to rearrange the equation to solve for W but the inclusion of F within the formula for WM makes the relationship between W and WM highly non-linear.

2.8.4 “Population approach”

Schaefer *et al.* (2007) describe two highly complex methods of determining recommended force limits for pushing and pulling that can be adapted to different user populations. The approaches consider strength distributions of the populations and compressive loads on the spine and have been incorporated into standards for pushing and pulling force limits. The complexity of the approaches, with the need to adjust for age and gender, and their lack of validation mean that they will not be considered further in this report.

2.9 WORKPLACE DESIGN GUIDELINES

Ferguson *et al.* (2005) set out to develop lifting guidelines specifically for low back injured workers to help prevent the recurrence of LBP arguing that most return to work practices are based upon subjective impressions as opposed to biomechanical logic. They defined low, medium and high-risk criteria for lifting zones at four heights and two horizontal distances from the body and for two levels of trunk symmetry and asymmetry. Using an EMG assisted biomechanical model they calculated spine loadings and compared the results to published spine tolerance levels to develop the guidelines for each zone. They showed that even a 4.5 kg load would create spine loads generating a “medium” risk of re-injury in some conditions. Their group’s previous work (Marras *et al.,* 2001) showed that the spine loadings of individuals with LBP were greater than the spine loadings of asymptomatic individuals. This was due to increased trunk muscle coactivation or “guarding” of the lumbar spine. LBP sufferers also compensated kinematically for their LBP to reduce the load moment.

The issue of injured workers returning to work on restricted or light duties, or short hours is of increasing significance because of the current recommendations under the biopsychosocial model of persuading LBP sufferers that they are better off at work than taking sick leave (Burton *et al.,* 2004; Burton *et al.,* 2005a; Clinical Standards Advisory Group, 1994; Staal *et al.,* 2003). Therefore there are important issues regarding how light duties are specified as there is little point in returning a recovering worker to the same job (Ferguson *et al.,* 2005), as even someone who considers the ergonomic track record to be "dismal" admits that work should accommodate us when we are ill (Hadler, 1997). To reinforce this, Ferguson *et al.* (2005) quoted figures showing that individuals with acute muscular occupational LBP required 12 weeks to recover functional performance while non-occupational patients required 8 weeks.

3 LITERATURE REVIEW – EPIDEMIOLOGY OF LBP

3.1 OVERVIEW

Dionne (1999) gives an overview of the epidemiology of LBP. He quoted figures showing that LBP constitutes 70 to 80% of all cases of spinal pain and that lifetime prevalence ranged between 54% and 84%. However, the six month prevalence of more severe cases of significant levels of disability dropped to 11%. Similarly, estimates of 1 year cumulative incidence vary between 17% and 34% but drop to 4.0% to 7.5% for medical consultation. The conclusion is inescapable that while LBP is common, it has severe consequences in only a small proportion of those affected.

Dionne (1999) quoted Waddell (1996) to make the point that evidence does not support an increase in the frequency of LBP in recent years but there has been a major increase in reporting low-back related disability and a consequent rise in compensation costs. Waddell (1998) makes these points in more detail.

Dionne (1999) listed four intimately interwoven consequences of LBP as:

- Activity limitation;
- Work absenteeism;
- Use of health services;
- Costs.

Dionne (1999) also discussed risk factors for LBP found in multivariate studies.

- Age and gender and socio-economic status were listed as having unclear effects. All of these are potentially confounded by levels of exposure, and the healthy worker effect.
- A history of LBP is the strongest predictor of future episodes of LBP. There is evidence that obesity and stature are predictors and other health problems such as osteoarthritis and other musculoskeletal diseases have strong associations with LBP.
- Occupational factors, such as frequent bending and lifting, awkward back postures, and whole body vibration, are well-documented risks, and specific traumatic injuries account for a significant proportion of low back problems.
- Depression, low self-confidence, and a propensity to somatisation are associated with LBP in cross-sectional studies but the evidence about whether such issues precede or follow the onset of back problems is equivocal.
- There is strong evidence, including a significant dose-response relationship, of the causal effect of cigarette smoking on LBP, but the contribution to the overall problem appears to be small. There was evidence that obstetric and gynaecological factors, as well as pregnancy affect the natural history of LBP in women.
- Few studies had focussed on seasonal variation in LBP incidence.

The economic consequences of work absenteeism due to LBP are the major drivers of the research that has been carried out on the topic. HSE (2004) report recent figures for the UK. As most LBP is of short duration, most workers recover relatively quickly and return to work. As a consequence, the longer a worker with LBP is away from work the less likely he or she is to return to work (Waddell, 1998).

Punnett *et al.* (2005) used epidemiological surveys from across the world to estimate the attributable fraction (AF) of LBP due to occupation. They found that men had higher exposure to both physical and psychosocial stressors due to greater participation in the labour force. They estimated that across the globe, 37% of LBP could be attributed to occupational risk factors, though the proportion varied twofold among regions, with a low of 21% and a high of 41%. The AF was generally higher in regions with lower overall health status but the regional differences were driven by labour force participation rate and population distribution of occupations, particularly farmers. They estimated that across the world work-related LBP caused the loss of 818000 "disability-adjusted life years" (DALYs) (World Health Organisation, 2006).

The natural history of LBP is normally described as having three phases:

- Acute (up to 4 weeks);
- Sub-acute (4 to 12 weeks); and
- Chronic (over 12 weeks).

This analysis does not reflect fully the nature of LBP where even when workers have returned to work they often still have pain and functional limitations (Dionne, 1999).

3.2 BIOPSYCHOSOCIAL ISSUES

A very highly cited review by Bongers *et al.* (1993) considered the relationship between psychosocial factors in the workplace and musculoskeletal disease. They noted that the majority of reports in the literature on the relationship between work stress and adverse health effects had concentrated on heart disease, gastrointestinal problems and general ill health, and that very few had investigated the relationship with musculoskeletal symptoms. They also found that the results of studies of chronic pain patients showed that individual psychological capacity is important when musculoskeletal symptoms are being dealt with. Thirdly, epidemiological research up to that point on musculoskeletal disease had largely concentrated on individual physical capacity and ignored the concept of psychological coping capacity or the interaction between physical load and coping capacity.

The authors suggested that possible associations between psychosocial factors, stress, individual characteristics and musculoskeletal disease were:

- Psychosocial factors potentially influencing mechanical load through changes in posture, movement and exerted forces through, for example hurried movements due to time pressure.
- Increased stress at work due to issues related to demands, control or support might increase muscle tone or enhance the perception of musculoskeletal symptoms or reduce an individual's capacity to deal with them, potentially leading to symptoms being prolonged or increased.

Therefore, the review addressed the issues of:

- The extent to which workplace psychosocial factors, as understood within the Demand Control Support model (Karasek and Theorell, 1990), were related to musculoskeletal symptoms, particularly in the back, neck and shoulder;
- How individual psychological variables influenced the relationship; and

- The role of stress symptoms, and whether the relationship between workplace psychosocial factors and musculoskeletal symptoms is specific or a general ill-health outcome.

They reported that the evidence for a relationship between back trouble and work demands was contradictory, particularly for time pressure, though there was a cross-sectional association with monotonous work. They found no longitudinal evidence. In a single longitudinal study, they found an association between poor social support at work and the incidence of back trouble. They found contradictory results in cross-sectional studies. In relation to personality traits and emotional problems, they reported that they were associated with back trouble in both cross-sectional and longitudinal studies. Also, associations in cross-sectional studies between stress symptoms and back trouble were tentatively supported by longitudinal studies. More generally, associations between back trouble and other symptoms of poor health were found in both cross-sectional and longitudinal studies but this disappeared in some cases after adjustment for other factors.

They considered separately the issues of symptoms and disorders of the neck or shoulders.

The majority of cross-sectional studies reported a relationship between psychosocial variables and symptoms of the neck and shoulders. There was evidence that variables such as monotonous work, time pressure, poor work content, and high workload were important. Longitudinal studies reported a positive relationship between time pressure and neck pain.

The data on the influence of social support on neck and shoulder symptoms were not consistent, but there was evidence that high demands, in combination with these variables and with high physical load at work, increased the prevalence of neck or shoulder symptoms.

Few studies analysed the relationship between psychological problems and neck or shoulder symptoms. There were scarce data on the relationship between these symptoms and social class or education and they did not suggest a strong relationship. However, based on cross-sectional findings, a relationship between stress symptoms or perceived stress at work and neck and shoulder symptoms seemed likely. On the other hand, no consistent relationship was observed between job dissatisfaction and neck or shoulder trouble.

In other body parts, monotonous work, time pressure and high perceived workload seemed related to musculoskeletal problems, and almost all studies reviewed stressed the importance of low control of the individual's job. Relationships were reported between psychological and emotional problems and musculoskeletal symptoms in the few studies that investigated the area. There also appeared to be a relationship between stress symptoms and musculoskeletal symptoms.

Summarising across body parts, they reported that the studies supported a relationship between monotonous work, perceived workload and work under time pressure and musculoskeletal trouble. Studies lent support to the relevance of social support at work, though the results were not consistent. A combination of job demands and support was consistently related to musculoskeletal trouble. Several emotional and psychological problems were related to musculoskeletal trouble but the role of these variables was not clear. Some longitudinal studies pointed to a role of stress in the development of musculoskeletal trouble. Overall, because of the variety of variables studied and the differing methods used to measure them it is difficult to draw overall conclusions. They also noted that most studies examined had relied on self-reports for symptoms and therefore the relationship between self-reported psychosocial factors and these symptoms was expected to be greater than between these variables and symptoms and signs established in a physical examination.

Their overall conclusion was that when all the reported data were combined, monotonous work, time pressure and perceived high work load showed positive relationships with musculoskeletal trouble though they did attribute part of this relationship to high mechanical loads associated with the variables.

They recommended longitudinal studies as of primary importance for future research as they may provide information on temporal relations and recommended drawing clear distinctions between risk factors for the development of musculoskeletal trouble, for the persistence of symptoms, and for the prediction of sick leave and disability. Therefore, they argued that these studies should pay attention to the independent effects of, and the interactions between, mechanical load, psychosocial factors at work and stress symptoms.

Linton and Skevington (1999) discussed the relationships between psychological factors and pain. They remarked that the task of untangling the relationships between them had been tedious and was still incomplete. The model they described of pain perception and behaviour had predisposing factors that, in combination with one or more triggers initiate a pain problem. Other factors, such as inappropriate behavioural responses, could maintain or catalyse the problem. Factors, such as depression, may adversely influence treatment prognosis while buffer factors such as active coping strategies may help people withstand pain problems. Another model they present involves cognition and learning and stresses the role of appraisal and beliefs. In the model, a painful stimulus is given meaning and evaluated as to its severity. A coping strategy results from this appraisal. The effect of the coping strategy on the pain is evaluated and fed back into the coping strategy. Thus, the individual may learn to avoid situations that will cause pain.

Coggon (2005) goes so far as to suggest that much illness and disability, including LBP, "which currently is attributed to injurious occupational exposure does not arise from underlying disease with detectable organic pathology, but rather is a psychologically mediated response to an external trigger that is conditioned by a combination of individual characteristics and cultural circumstances." Santana (2005) found Coggon's explanation neither totally clear nor convincing and noted that the lack of (current) objective detectable or measurable biological evidence of a disease is not a requirement for its recognition and acceptance of relevant evidence of human suffering. Kogevinas (2005) commented that the evidence that Coggon questioned is more extensive than that evoked by him to refute it.

3.3 SCOPE FOR PREVENTION OF LBP

It has to be recognised that as LBP is almost universal, the prospect of preventing it is reduced and eradication would be impossible (Dionne, 1999; Hadler, 1999; Waddell, 1998). Therefore one aim must be to seek to reduce the associated disability and to control the pain (Waddell, 1998; Clinical Standards Advisory Group, 1994; Leamon, 1994b). Burton *et al.* (2005a) stated that, "Musculoskeletal symptoms are highly prevalent in the population, and often resolve uneventfully, although recurrence is common."

Recent European guidelines (Burton *et al.,* 2004) on prevention of LBP argue that there is limited scope for preventing its incidence (first time onset). They noted that primary causative mechanisms remain largely undetermined and that risk factor modification will not necessarily achieve prevention. They focused therefore on the prevention of the consequences of LBP through reduction of the impact of recurrences, care seeking, disability and work-loss. Their overarching comment was that there was acceptable evidence that the prevention of various consequences of LBP is feasible but that the effect sizes of the interventions are rather modest. They concluded that the most promising approaches were physical activity/exercise and education in the biopsychosocial model of LBP.

A less despairing view is espoused by McGill (2002). In a section entitled "Deficiencies in Current Low Back Disorder Diagnostic Practices" he writes:

> *"It is currently popular for many authorities to suggest that back trouble is not a medical condition. They assert that physical loading has little to do with low back injury compensation claims; rather they believe workers complain of back problems in order to benefit from overly generous compensation packages or to convince physicians they are sick. According to this view any biomechanically based injury prevention or rehabilitation program is useless. Variables within the psychosocial sphere dominate any biological or mechanical variable. If this is true, then this book is of no value—it should be about psychosocial intervention."*

He is hardly gentle when he comments that:

> *"The position that biomechanics plays no role in back health and activity tolerance can be held only by those who have never performed physical labor and have not experienced first hand the work methods that must be employed to avoid disabling injury. While the scientific evidence is absolutely necessary, it will only confirm the obvious to those who have this experience."*

While he does not discuss the epidemiological literature with the approach usually taken in systematic reviews or meta-analysis, McGill (2002) provides an overview of the epidemiological literature and highlighted studies (Bigos and Battie, 1987; Snook *et al.,* 1978) that support his contention that both psychosocial and biomechanical factors are important risk factors for LBP. He then provides an extensive discussion of the anatomy and normal and injury mechanics of the lumbar spine. Finally, he discusses in detail risk reduction guidelines aimed at reducing the overloading stressors that cause occupational LBP and rehabilitation and exercise programs.

Pre-employment screening has a chequered history and no evidence of effectiveness (Snook, 1987). Early methods involving x-rays merely increased radiation dosages (Gibson *et al.,* 1980). A more recent approach has been to attempt to select for physically demanding occupations by pre-employment strength and fitness tests (Rayson *et al.,* 2000).

Training in lifting techniques also lacks strong evidence (Daltroy *et al.,* 1997) though training providers challenge this work (Downing, 2006; 2004; Liles, 1986) with criticisms of the training methodology applied and anecdotal reports of the efficacy of their own programs.

Dionne (1999) argued that given the recognition of the importance of occupational factors in LBP, ergonomic interventions appear to be crucial in prevention, but the complexity of implementing and evaluating interventions means that the evidence of their effectiveness is limited. He noted that there is still much to learn about LBP and insisted that:

> *"etiological studies on LBP must focus on specific factors and test specific models of interaction between the most important factors, and stop the repeated 'fishing expeditions' or the testing of 'laundry lists' of variables".*

More optimistically, a study by Lahiri *et al.* (2005) examined the cost-effectiveness of the different interventions that have been attempted in the past. They estimated that LBP/injury could be reduced by 20% with training, by 56% with engineering/administrative controls, by 60% with a combination of engineering/administrative controls and training and by 74% by a comprehensive workplace Ergonomics Program. They considered cost effectiveness of these programs taking into account worldwide differences in levels of industrialization. Their findings suggested that full ergonomics programs would be cost-effective in both developed and developing countries for their health effects alone. However, they did conclude that training appeared to be the most cost-effective intervention, despite the impact of training on health outcome being rather limited. While they were more expensive, engineering and ergonomics interventions had a far greater impact on total health outcome than training due to the greater reduction in LBP incidence.

They recommended prospective studies of the recurrence of LBP and studies of workers who are the “working hurt”.

They believed that worker training is a low cost feasible first step towards the reduction of work-related LBP in developing countries where resources are scarce and that it should be encouraged through public policy and regulation. However they considered it unquestionable that ergonomics programs should be encouraged in highly developed countries for both health and productivity effects and that when additional resources become available they should go straight to the full ergonomics programs.

3.4 PREVIOUS PROSPECTIVE STUDIES OF LBP

3.4.1 Physical risk factors

A small number of prospective studies of physical risk factors for LBP are summarised in Table 11. This is not a systematic review but concentrates on recent studies looking at physical risk factors for individuals in the workforce. Particular emphasis is given to the Dutch SMASH (Study on Musculoskeletal Disorders, Absenteeism, Stress, and Health) study that has looked at a wide range of relevant issues. A large number of other studies that have been reported in recent years have not been included in this summary.

Table 11 Summary of selected longitudinal studies

Study/citation	***Population / measures***	***N***	***Follow-up***	***Incidence***	***Other findings***
SMASH (Hamberg-van Reenen *et al.,* 2008)	Dutch workers from 34 companies; subcohort with "No" or "Sometimes" pain in the 12 months prior to baseline and at least one follow-up	Baseline 1789; subcohorts from 865 - 1119	Three years	9.8% LBP (3.3% per annum)	5.8% neck pain (1.9% per annum) 5.4% right shoulder pain 5.8% left shoulder pain
SMASH (Hoogendoorn *et al.,* 2000a)	Dutch workers from 34 companies; subcohort with no regular or prolonged LBP in the 12 months prior to baseline; LBP data for three follow-ups; data on trunk flexion, rotation and lifting	Baseline 1789; LBP free subcohort 1192; three follow-ups 861; lifting 835	Every 12 months for three years; by post; NMQ	Cumulative incidence of LBP 26.6% (24.7% males, 30.8% females)	
SMASH (Hoogendoorn *et al.,* 2001)	Dutch workers from 34 companies; subcohort with no regular or prolonged LBP in the 12 months prior to baseline; LBP data for three follow-ups	Baseline 1789; LBP free subcohort 1192; three follow-ups 861;	Every 12 months for three years; by post; NMQ		
SMASH (Hoogendoorn *et al.,* 2002b)	Dutch workers from 34 companies; subcohort with company sickness absence data (21 companies)	Baseline 1789; subcohort 988; with sickness absences reasons 732; with work-related physical factors data 702	Data from company absence records sent every 12 months	Males: 11.35 absences per 100 person years; females: 5.82 absences per 100 person years	149 individuals (20.4%); 100 absent once, 24 absent twice, 14 absent three times, one absent four times.
SMASH (van den Heuvel *et al.,* 2004)	Dutch workers from 34 companies; subcohort with company sickness absence data (21 companies)	Baseline 1789; subcohort	Every 12 months for three years; by post; NMQ		
BelCoBack (van Nieuwenhuyse *et al.,* 2006)	Employees of four healthcare and two distribution companies in Belgium; permanent employees; age ≤ 30; no LBP episode lasting ≥ seven days in previous 12 months.	Baseline 972; 851 with ≥ 2 months in post; follow up 716 (84%)	12 months	12.6% (n = 90 / 716)	

Study/citation	***Population / measures***	***N***	***Follow-up***	***Incidence***	***Other findings***
EuroBack Unit prospective cohort study (Gheldof *et al.,* 2007)	Industrial workers from 10 companies in Belgium and the Netherlands	Baseline 1294 (11% of those approached); follow up 812; 90% male	Baseline measures + 18 month follow up by postal survey. Both asked about LBP in the previous 12 months	Baseline prevalence of LBP (one or more days LBP in the previous year) 69%; sick leave due to LBP reported by 36%.	
South Manchester Back Pain Study (Papageorgiou *et al.,* 1997)	Employed adults registered with two primary care practices and free of LBP at baseline; consultation with physician over 12 months and postal questionnaire after 12 months to identify episodes not resulting in consultation	1412 at baseline; 784 follow-up (58%)	12 months	Consultation 63 / 1412, i.e. 4.5% (3.4% males, 5.4% females) LBP but no consultation: Retrospective reports 31.5% (247 of 784 respondents)	

3.4.2 Psychosocial risk factors

A systematic literature review (Hoogendoorn *et al.,* 2000b) as part of the SMASH study looked at evidence for psychosocial factors at work or home as risk factors for LBP (Table 12):

Table 12 SMASH review of psychosocial factors at work

Risk factor	***Studies***	***Assessment***	***Reason***
Work pace	Three high quality	Insufficient evidence	Inconsistent findings
Qualitative demands	One high quality; one low quality	Insufficient evidence	Inconsistent findings
Job content	Four high-quality	Insufficient evidence	Only one usable study available
Job control	One high quality	Insufficient evidence	Only one study available
Decision latitude	One high quality	Insufficient evidence	Only one study available
Social support	Five high quality; one low quality	Strong evidence	RR/OR between 1.3 and 1.9
Job satisfaction	Seven high quality; two low quality	Strong evidence	RR/OR between 1.7 and 3.0

Of the studies of psychosocial factors in private life, they categorised one as high quality and two as low quality, but the factors studied were very varied. They concluded that there was insufficient evidence to draw conclusions on the effect of psychosocial factors in private life.

They found that none of the studies of low job satisfaction adjusted for physical load at work. The positive association between low job satisfaction and LBP may be due to an inter-correlation between psychosocial work characteristics and physical load on one hand and job satisfaction on the other. They noted that, in general,

> *"in many of the studies no adjustment had been made for physical load at work".*

Hoogendoorn *et al.* (1999) had concluded that,

> *"Strong or moderate evidence has been found for heavy physical work"*

and,

> *"The body of evidence supporting the role of these physical load factors as risk factors for back pain is somewhat more consistent than that for the psychosocial factors."*

A related study (Hoogendoorn *et al.,* 2001) of 861 workers investigated relationships between the occurrence of regular or prolonged LBP over a 12 month period and: Quantitative job demands; Conflicting demands; Decision authority; Skill discretion; Supervisory support and Co-worker support. These were measured with a modification of Karasek's Job Content Questionnaire (JCQ). The study took into account the potential confounding effects of individual factors and physical load at work.

The cumulative incidence of LBP was 26.6% over three years. Most univariate relationships of work characteristics were not or only marginally significant. Only high quantitative job demands or medium co-worker support were significant. Multivariate analyses did not show any significant Relative Risks (RRs).

For the psychological strain variables significant relationships were found for:

- Less than good job satisfaction;
- High emotional exhaustion;
- High score for sleeping difficulties.

They concluded that there was no support for the hypothesis that the association between psychosocial work characteristics and LBP is based on confounding by physical work factors. There was no evidence that psychological strain variables had an intermediate role in the relationship between psychosocial work characteristics and LBP.

3.4.3 Psychosocial risk factors as predictors of MSD related absence

Bartys *et al.* (2005) reported a prospective study exploring the predictive relationship between psychosocial risk factors and absence due to MSDs of the back and upper limbs. Of 4637 participating workers (59.2% of the workforce) employed by a large multi-site pharmaceutical company, 219 (4.72%) took absence due to MSDs over a 15-month period (annual incidence rate of 3.78%). The psychosocial factors considered were measured at baseline and were “Psychological distress”, “Job satisfaction and social support”, “Perceived control at work”, “Organizational climate”, and “Workplace causal attribution”. Self-reports of MSDs in the previous 12 months in the low back and upper limb were collected using the Nordic Musculoskeletal Questionnaire (NMQ). Workplace absence incidence and duration data were obtained from company records

Cut-off points were determined for the psychosocial scales to define risk of MSDs on each scale. They found that the scores above these cut-off points were predictive of the occurrence of future absence due to MSDs but not its duration. They concluded that routine psychosocial screening to predict disability is of limited value because of the relationship between psychosocial risk factors and MSDs is more pertinent when an individual has developed persistent symptoms.

An associated research report (Burton *et al.,* 2005b) reported clear cross-sectional baseline associations between self-reported musculoskeletal symptoms and a wide range of psychosocial measures for both LBP and upper limb disorders (ULDs). Both workplace-related psychosocial factors and psychological distress were independently predictive of future absences but not their duration. The psychosocial mechanisms did not fully explain absence behaviour.

3.4.4 The stress and MSD study

This was an HSE funded study carried out by Surrey University. It has been reported in an HSE Research Report (Devereux *et al.,* 2004) and a paper focussing on the issue of lay beliefs (Rydstedt *et al.,* 2004). From a sample population of 8000, usable baseline questionnaires were obtained from 3139. The questionnaire used psychometrically tested and validated question sets to measure work organisation factors, psychological factors, physical work factors and MSD outcomes in six body parts, and psychological (stress) outcomes on ten scales. Longitudinal follow-up of the respondents took place 15 months later with an 86% response rate from those still employed in the jobs they were in at baseline. The report does not specify what the follow-up questionnaire consisted of or what constituted an incident case, but separate reports were obtained for the six body parts. In order to reduce problems of accuracy in exposure assessment inherent in using a questionnaire, they categorised workers dichotomously so that there was good contrast between the two exposure groups.

With regard to work-related stress, they found that workers highly exposed to physical and psychosocial work risk factors had the greatest likelihood of reporting high perceived job stress at baseline, but this was not found in the longitudinal study. Individual psychosocial work factors associated with high perceived job stress at both baseline and longitudinally were “extrinsic effort”, “intrinsic effort”, “role conflict”, “verbal abuse” and “confrontations with clients or the public”.

High exposure to physical and psychophysical work factors was associated with baseline self-reported musculoskeletal complaints in six body parts. Longitudinally, high exposure to both factors increased the odds of new episodes in the low back, neck, shoulder, elbow and forearm, and the wrist/hand. Psychosomatic symptoms increased the likelihood of reporting new episodes of complaints in the upper back, shoulder and hand/wrist.

3.5 STUDY DESIGN ISSUES

3.5.1 The nature of LBP

LBP is often a recurrent condition (Waters *et al.,* 1993) and hence episodic (Eisen, 1999). Von Korff (1999) noted that most adults experience recurrent pain of some form, with a significant minority experiencing severe chronic pain, but relatively few experiencing major disability. Pain is changing and dynamic rather than fixed and static.

An epidemiological perspective (Von Korff, 1999) considers risk factors for LBP to control or predict the probabilities of onset or progression and to fall into the categories of initiators, promoters, detection factors and prognostic factors. Initiators set in motion a causal process, with promoters enhancing or potentiating such a process after it has started. Detection factors increase the probability of a case being identified and prognostic factors influence or predict the clinical course.

Episodic conditions such as MSDs do not have simple courses of progression over time from incidence (initial occurrence) to resolution or death. Therefore, the prevalence depends upon not only the incidence of new cases and mortality (almost exclusively from other causes) of prevalent cases, but also the duration of the morbid episodes before remission or resolution, and on the recurrence frequency and intervals between episodes. Von Korff (1999) commented that as a result, differences in prevalence rates by risk factor status should be interpreted with care.

As MSDs are a mixture of acute and chronic cases and estimates of population lifetime prevalence are in the range of 50% to 80%, the situation is quite complex. In such circumstances, it is difficult to establish the initial point of onset, to differentiate new episodes from recurrences and to distinguish levels of severity of the condition.

Issues of inferring causality in such conditions are complicated by the multifactorial causes, by single risk factors producing multiple effects (“multiplicity of effect”) and by the ability of a range of risk factors or causal paths to produce the same effect (“equifinality of effect”). The existence of feedback loops which affect both the person with the pain and the context in which they live are also significant. In other words, psychosocial factors such as “pain behaviours” or “fear-avoidance beliefs” can affect a person’s social environment, and vice versa.

3.5.2 Available epidemiological study designs

Observational studies collect data in existing situations, which may or may not be selected. Experimental studies manipulate exposure to risk factors to examine the effect of systematic variation of them. Cross-sectional studies involve collecting data from a population at a single time point. They can be used to demonstrate associations between measured factors and outcomes such as measurements of prevalence of pain. They are incapable of showing causal relationships between the measured factors and outcomes due to the lack of evidence of a temporal relationship between exposure to a risk factor and the later incidence of the outcome. Longitudinal studies (also known as prospective, or cohort studies) involve observing the same units of study (usually individuals) on more than one occasion, which allows the examination of temporal relationships between risk factors and outcomes. This can, in the context of the other necessary evidence (such as plausible mechanisms) allow the conclusion to be drawn that there are causal relationships between risk factors and outcomes. Once such a conclusion has been drawn, the relationships can be tested in experimental studies where the risk factors are manipulated and the effects on the outcome variables measured. Longitudinal studies are therefore treated as a gold standard for providing evidence of causality and therefore for identifying credible interventions to reduce the outcome of undesirable health outcomes such as LBP.

Von Korff (1999) therefore noted that longitudinal studies can help us understand the fluctuating course of pain and the extent to which pain syndromes go into remission, recur or progress.

3.5.3 Methodological issues

Important considerations in longitudinal studies relate to the need to take repeated measurements over time. Von Korff (1999) distinguished three effects measurable by them:

- Aging effects representing measured changes due to natural ageing processes
- Cohort or period effects representing the contribution of past history of unique experience of a cohort to their series of measurements
- Time effects representing the effect of the passage of time between measurements

These studies require surveillance of the cohort over time to provide reasonably precise detection of the events of interest that occur during the follow-up period. Repeated or serial measurements of the same variable tend to be correlated and are therefore not independent. In addition, a plausible underlying statistical model must be specified. The analysis has to be based on a comparison of incidence rates for different exposures or levels of exposure (Von Korff, 1999).

Crombie and Davis (1999) noted that studies of the natural history of a pain condition require a homogenous set of underlying pathophysiological processes. Unfortunately, this criterion is often difficult to meet in studies of MSDs due to a lack of knowledge as to the source of the disorder or even the precise location of the problem. This is particularly so in studies which rely on self-reports of problems rather than on clinical examination and differential diagnosis. They also noted that pain, which may be the only symptom of a musculoskeletal problem, is a subjective experience, thus creating problems for measurement.

3.5.4 Sources of bias in longitudinal studies

- Participation bias: As longitudinal studies of this kind depend upon voluntary participation, there is an uncontrollable source of bias in that the companies and individuals who agree to participate might be different in important ways to companies and individuals who refused to participate. The attitude of companies toward a laboratory that is part of an enforcing agency will have influenced their willingness to participate, and it would be expected that companies with worse health and safety records would be less willing to have such contact with HSL.

- Loss to follow-up and missing data: Missing data and loss to follow-up can substantially reduce sample size, particularly where multiple observations are made. These issues are often not random but result in differential attrition, thus creating bias in the measurements and conclusions.
- Measurement bias: Measurement bias can result from measures eliciting different responses on repeat administration or from drift over time. There is a danger that biased or unreliable measurements can overwhelm the magnitude of the true effects in a longitudinal study (Von Korff, 1999) resulting in a low signal to noise ratio.

Bernard (1997) listed other possible sources of bias as:

- Selection bias: In other words, the study population needs to represent the whole working population under consideration. Part of this can be represented as the “healthy worker effect” due to selection of healthy workers into a particular workforce or the loss of unhealthy workers from the workforce.
- Generalizability (external validity): The assumption is that the study sample represents the whole working population. In addition, it is assumed that MSD cases in one study are comparable to cases in another study. This needs particular care due to the variation that exists between case definitions.
- Misclassification bias: This can occur in both measurement of exposure and determination of case status. Risk ratios will tend to be diluted if this happens equally for both cases and non-cases.
- Confounding and effect modification: Confounding occurs when another variable affects the apparent relationship between exposure and the outcome. An effect modifier alters the effect of exposure on disease
- Sample size, precision and confidence intervals (CIs): The larger the study the more precise is the estimate of the risk and the smaller the CI. Of course, power affects the ability of the study to identify real effects, so the larger the sample is, the more powerful is the study.

4 DESIGN OF THE STUDY

4.1 INITIAL STUDY DESIGN

The project was designed to replicate a project carried out in the USA by the Liberty Mutual Research Institute and Texas Tech University, with funding from Liberty Mutual and NIOSH.

The purpose of the Liberty Mutual study was to carry out a prospective evaluation of the ability of the 1981 and 1991 NIOSH Lifting Equations to predict work loss due to LBP in workers employed in jobs requiring manual handling. The study design called for measurements to be taken of the jobs at baseline and for subjects to fill in a baseline questionnaire. The follow-up was specified as contacting subjects every three months for 18 months to record incident cases of lost time due to LBP.

The US scientists who developed the original project protocol (Ayoub, 1996; Dempsey, 1998) were:

- Professor MM Ayoub of the Department of Industrial Engineering, Texas Tech University. The study protocol was developed in the light of work done by Professor Ayoub's PhD students in the early 1980s on the Job Severity Index (Liles, 1986; Liles *et al.,* 1984).
- Professor Peter H Westfall of the Department of Information Systems and Quantitative Sciences, Texas Tech University. Professor Westfall is a professional statistician and the principal developer of PROCMULTTEST of SAS/STAT.
- Dr. Patrick G Dempsey of Liberty Mutual Research Institute (previously Liberty Mutual Research Center). Liberty Mutual has been involved for many years in research related to LBP, particularly psychophysical studies of manual handling, such as Snook and Ciriello (1991). Dr. Dempsey did his PhD at Texas Tech under Professor Ayoub's supervision and then joined Liberty Mutual. In late 2007 he moved to the NIOSH Pittsburgh laboratory.

Liberty Mutual initially sought to collect prospective data for 2000 subjects in the USA (Ayoub, 1996). Due to difficulties in finding sufficient subjects in suitable jobs, they stopped recruiting subjects having obtained only 449 out of the intended 2000. They had also experienced an annual dropout rate of 46%. They estimated their costs to have been approximately $1,000,000.

A number of papers have been published which describe the Liberty Mutual project and discuss the problems experienced. The areas covered include:

- Issues of study design (Dempsey *et al.*, 1995; Dempsey and Westfall, 1997; Dempsey *et al.,* 1997).
- Measurement issues (Dempsey, 1999; Dempsey and Fathallah, 1999; Dempsey *et al.,* 2001).
- The results of the study (Dempsey *et al.*, 2000; Dempsey *et al.*, 2002; Dempsey, 2001).
- The usability of the equation (Dempsey, 2002).
- The nature of the jobs included in the study (Dempsey, 2003).

4.2 THE NEED TO RESCOPE THE HSL STUDY

HSL initially offered to use the Liberty Mutual protocol to collect data on 200 subjects in the UK, again over an 18 month follow-up period and to pool the data with Liberty Mutual for joint analysis. HSL had not started subject recruitment had not started before the difficulties experienced by Liberty Mutual became apparent. Progress to that stage at HSL had included identification of firms to approach to take part in the study and rewriting of data collection protocols and survey instruments supplied by Liberty Mutual to reflect additions being made to the HSE/HSL study protocol.

Since Liberty Mutual had not reached their target number of subjects, the power of their study had been significantly reduced and it was not be able to meet its original objectives. It was realised (Pinder, 2002b) that the addition of 200 subjects by HSL to the 450 recruited by Liberty Mutual would not have been sufficient to rectify the problem of a lack of power.

Comparison with another study (Hoogendoorn *et al.,* 2000a) that reported a 20% dropout rate over two years showed that the Liberty Mutual study appeared to be unusual in suffering a dropout rate of 46% in under a year. It was therefore considered that it was not inevitable that a matching study in the UK would the same problem and that it was worth proceeding with the project with an increased number of subjects.

4.3 ORIGINAL STUDY AIMS / HYPOTHESES TO BE TESTED

The proposal from Texas Tech (Ayoub, 1996) set out five specific aims. The aims of the UK study, as stated in the original job plan for the project, followed them closely, with the addition of the evaluation of the EN and ISO equations. Both sets of aims are reproduced verbatim in Table 13. The major difference is the addition of Aim 3 in the HSL job plan, which specifies that the ISO and EN lifting equations should be evaluated in the same way. As a result, Aim 3 in the Liberty Mutual proposal became Aim 4 in the HSL job plan and was modified to reflect the inclusion of these two equations. It was therefore implicit that the additional multipliers introduced into the EN equation should be subjected to the same kind of validation as the multipliers in the NIOSH equations.

Table 13 Aims and objectives of the Liberty Mutual and HSL studies

Liberty Mutual specific aims (Ayoub, 1996)	*HSL Aims and Objectives*
—	"The project will provide evidence for the capability of the NIOSH equation to predict the incidence and severity of low back disorders.
"1) To prospectively determine if the LI for jobs from various industries is related to the incidence and severity of lowback disorders. The ratio of actual weight lifted to the 1981 action limit (AL) (NIOSH, 1981) will be evaluated for comparison purposes. The lifting indices based on the 1981 and 1991 equations will be referred to as LI81 and LI91 respectively, when distinction is necessary.	"1) To prospectively determine if the Lifting Index (LI) for jobs from various industries is related to the incidence and severity of low-back disorders. The LI is the ratio of actual weights lifted to the Recommended Weight Limit (RWL) which arises from applying the 1991 revised NIOSH lifting equation.
"2) To prospectively determine if the relationship between the LI value and probability of low- back injury is different for workers of different sex, age, height, weight, and history of prior low-back pain or injury episodes. Other job-related factors, such as percent cycle time that includes lifting or lowering, not included in the NIOSH equations, will also be examined.	"2) To prospectively determine if the relationship between the LI value and the probability of low back injury is different for workers of different sex, age, height, weight, and history of previous low-back pain or injury.
—	"3) To similarly evaluate how the requirements in the current ISO and CEN proposals for standards on manual handling are related to the incidence and severity of low-back disorders.
"3) To compare the current functional forms of the four multipliers that are continuous (i.e. VM, HM, DM, AM as defined by Waters *et al.* (1993) to empirically determined relationships between V, H, D, and A and the incidence of back injuries. The relationship between frequency and injury will also be compared to the frequency multipliers; however, the frequency multipliers were designed based on physiological concerns (Waters *et al.,* 1993). The analysis will include provisions for assessing the relationship between the three levels of couplings (good, fair, and poor) and injury. The analysis will also allow for comparisons between the 1981 multipliers and the empirically determined functions, some of which are very similar in form to their 1991 counterparts. The functional forms of several of the 1981 and 1991 multipliers that are continuous are illustrated in Figures 1 - 2.	"4) To empirically determine relationships between vertical distance (V), horizontal distance (H), lift distance (D) and asymmetry (A), and the incidence of back injuries. To compare these relationships with that of the functional forms of the equivalent multipliers in the NIOSH lifting equation (and their ISO/CEN equivalents). Similar comparisons of frequency and level of hand to object coupling will also be carried out.
"4) To determine if an alternate injury prediction model developed from the data collected that incorporates the 6 variables currently represented in the RWL equation, personal variables, job-related factors, and their interaction terms would be more appropriate than the NIOSH equation or useful as a supplement.	"5) To determine if an alternate injury predictive model developed from the data collected could either replace or supplement the NIOSH equation.
"5) To qualitatively evaluate the usability of the new equation in practical situations. Problems encountered during data collection and during computation may suggest alternative data collection procedures and analysis methods."	"6) To qualitatively evaluate the usability of such a new model in practical situations."

4.4 REVISED STUDY PROTOCOL

The NIOSH equations are important as job design and manual handling risk assessment tools and the EN and ISO standards (BS EN 1005-2, 2003; ISO 11228-1, 2003) are derived from them. Therefore, the need remained to evaluate them as predictors of safe loads for lifting, and hence of the risk of LBP.

It was therefore decided to carry on with the HSL study and to revise the protocol to increase the statistical power in an attempt to overcome some of the problems experienced by Liberty Mutual.

The revised protocol called for the recruitment of a range of companies from across the UK to participate in the study. The target was set of recruiting in the region of 50 workers per firm. Subsidiary outcomes of interest were defined as reporting LBP without work loss or reporting LBP causing the worker to be put on light duties or reduced hours at work.

The major changes made when the protocol was revised were:

- An increase in target sample size from 200 to 1000;
- The inclusion of additional LBP outcomes;
- The addition of the use of the NMQ to collect baseline prevalence data of musculoskeletal trouble;
- The addition of a questionnaire to collect psychosocial data at baseline.

Care was taken to ensure the two studies remained compatible to allow the proposed pooling and joint analysis of the data. The follow-up period was kept at 18 months. The major outcome of interest was kept as low back injury causing absence from work.

At the request of HSE, HSL sought epidemiological advice on the proposed revisions to the protocol from Dr. Lesley Rushton, formerly of the Institute for Environment and Health (IEH) of the University of Leicester, now of Imperial College in London. Her main research area has been in epidemiological aspects of occupational and environmental health.

Since the project started, HSL and HSE produced the Manual handling Assessment Charts (MAC tool) (Health and Safety Executive and Health and Safety Laboratory, 2003; Monnington *et al.,* 2002; Monnington *et al.*, 2003). These are designed to aid regulatory inspectors inspecting workplaces in identifying high-risk features of manual handling operations to allow them to target enforcement action or advice. The charts cover lifting, carrying and team handling. They are based on a traffic light system that uses colour coding to identify high levels of risk for each risk factor in the chart. Associated with the colour codes are numerical scores that can be totalled to give an overall score. The MAC was developed in the light of the existing tools, such as the 1991 NIOSH equation. Moreover, when the MAC was being developed it was realised that the data then being collected for this project could also be used to evaluate the ability of the MAC tool to predict the likelihood of LBP or lost time due to LBP due to manual handling.

4.4.1 Summary of HSL methodology

- With the help of participating companies, jobs involving manual handling tasks suitable for inclusion in the study were identified.
- Workers who performed these jobs, and that agreed to participate were asked to complete a consent form and a baseline questionnaire (Appendix 1).

- Measurements of the variables necessary to calculate the NIOSH LI were taken of the work tasks these workers carry out which involve manual handling. This included video recording of the tasks.
- Subjects were followed up to record injuries at work and lost time from work over the following 18 months. Subjects were contacted at home every three months over the 18 months to ask whether they were still working in the same job and about any LBP or injuries at work.
- After 9 months and 18 months, companies were asked to send details of any accidents that had happened to these workers in the intervening period and of any sick leave they had taken as a result.
- HSE databases were searched for reports of injury-related absences from work of more than three days.
- The analysis methods specified included logistic regression and Cox regression.

4.4.2 Increase in target number of subjects

The preferred method of analysis for longitudinal data sets is Cox regression, which is also known as survival analysis or Proportional Hazards Modelling (PHM), though the original Liberty Mutual proposal (Ayoub, 1996) also specified the use of logistic regression. Cox regression uses as its primary dependent variable the time that each subject survives in the study population until an event of interest occurs. Hosmer and Lemeshow (1999) discuss survival analysis in detail. The proposed analysis methods for the Liberty Mutual study, including non-linear extensions of survival analysis using General Additive Models (GAMs) (Hastie and Tibshirani, 1990) have been discussed in detail (Ayoub, 1996; Dempsey *et al.,* 1997; Dempsey and Westfall, 1997; Dempsey, 1999) and reproduced in the HSL study protocol (Pinder, 2001).

Available computer software for calculation of power and sample size lacked options for GAMs or for Cox PHMs that were more complex than binary comparisons. Therefore, a PHM was used to estimate the power of a comparison of lost-time due to back injury between a control group ($LI < 1$) and an exposed group ($LI \geqslant 1$). A range of sample sizes, two levels of risk and two levels of dropout were used. A 5% incidence rate was assumed in the control group. Rates of 26.4% (Marras *et al.,* 1995) and 10% (Kraus *et al.,* 1997) were used for high and conservative estimates of the incidence in the exposed groups. Annual dropout rates of 10% (Hoogendoorn *et al.,* 2000a) and 46% (Dempsey *et al.*, 2000) were used.

The calculations were carried out using the “advanced log rank two-sided Proportional Hazards Model” in PASS (“Power Analysis and Sample Size”, NCSS, Kaysville, Utah). It was assumed that the control group would be equal in size to the exposed group and that subjects would be recruited over 9 months and followed up for 18 months each. Conventional significance and power levels of 5% and 80% were used.

Table 14 Effect of RR, dropout rate and sample size on power

Risk	*Annual dropout*	*N = 200*	*N = 450*	*N = 650*	*N = 1,000*	*N = 2,000*
Conservative (RR = 2.0)	10%	0.360	0.670	0.822	0.947	0.999
	46%	0.268	0.519	0.674	0.848	0.988
High (RR = 5.3)	10%	0.997	1.000	1.000	1.000	1.000
	46%	0.979	1.000	1.000	1.000	1.000

The results (Table 14) of these calculations indicated that a sample size of 200 would provide very little power for the conservative risk estimate. A sample of 650 would provide the conventionally necessary 80% power at an annual dropout of 10%, provided the other assumptions are met. A sample of 1000 would provide this power if the dropout rate reached the 46% experienced by Liberty Mutual. In the unlikely circumstance that all jobs in the exposed group fell into the high risk category, very great power would be obtained, even with a sample of 200 and an annual dropout of 46%.

It was realised that a full evaluation of the 1991 NIOSH equation requires testing the ability of each of the constituent multipliers to predict lost time. Sample sizes required to do this were estimated by assuming that variations in all but the multiplier of interest can be treated as random errors and that there is a perfect inverse relationship between the multiplier and the RR of LBP, so that a decrease in a multiplier from 1.0 to 0.5, reflects a true doubling of risk. Because the multipliers have a range of minimum values, calculations were carried out for values between 0.9 and 0.1, using both the conservative and high RR estimates (Table 15).

Table 15 Effect of multiplier value on required sample size

Multiplier value	*RR equivalent to multiplier*	*"Conservative" overall risk (RR = 2.0)*		*"High" overall risk (RR = 5.3)*	
		% surviving	*Required N*	*% surviving*	*Required N*
1	1.00	95.0%		73.6%	
0.9	1.11	94.4%	35,342	70.7%	5,417
0.7	1.43	92.9%	2,724	62.3%	403
0.5	2.00	90.0%	615	47.2%	86
0.3	3.33	83.3%	162	12.0%	20
0.1	10.00	50.0%	28	0.0%	0

The results show that the ease of assessing a multiplier depends upon the range of values it can take. Thus, DM, which can decrease to 0.85, is much harder to evaluate than FM, which can decrease to zero. To evaluate CM would require tens of thousands of subjects if the overall risk were anything but high. Moreover, because all except CM are continuous variables, values distributed across the range of each would be needed for a full evaluation, which will to increase the sample size required. The subject numbers required to evaluate the additional multipliers in the EN equation were also examined by Pinder (2002b). Because the values that these multipliers take when the risk factor is present are all smaller than the minimum value of the CM, the CM represents the worst case for sample size.

These calculations were used to inform the rescoping of the HSL part of the study. A target of 1000 subjects was chosen as a compromise between the need to keep the study size within manageable bounds and available resources and the need to provide meaningful results. With a 10% annual loss to follow-up, power of 95% for an alpha value of 5% was expected for the evaluation of the overall predictive abilities of the NIOSH and EN and ISO equations, if the RR is 2.0. Even if the dropout rate reached the 46% experienced by Liberty Mutual, the power would still be 85%. It was realised that this sample size might be sufficient to evaluate the more important individual factors within the equations, but would definitely not be sufficient to evaluate the least influential.

4.4.3 Addition of outcome / incidence measures

To help capture the complexity of the effects of LBP and variations in severity, additional outcome measures were defined. In addition to LBP that caused work loss, subjects were asked to report LBP that did not affect their work or that resulted in them being placed on light duties or restricted hours at work.

Because there is often confusion over whether or not LBP is caused by an “injury” (Manning *et al.,* 1984; Pheasant, 1991), a separate outcome measure of “injuries at work” was also added, with the same categories. This also had the advantage of avoiding the confusion that could result from using what Leamon (1994b) delicately calls “unusual dependent variables” such as medical room visits without separation of “contact injuries” from “musculoskeletal incidents” or “back incidents” (Herrin *et al.,* 1986).

The advantage of providing multiple measures of severity of the outcome measures in this way is that greater power is provided since larger proportions of the study population will experience LBP that is non-disabling than will experience LBP that causes work loss. Thus, while LBP resulting in work loss is economically significant, non-work loss related LBP is significant physically to the individuals suffering from it. Therefore, if associations or causal relationships can be shown with it, interventions to reduce its incidence and severity can be justified.

Since the follow-up questionnaires asked for reports of LBP that did not result in work loss (“Work not affected”), some of the data obtained were in the form of repeated panel data, i.e., prevalence data for successive three month periods. Such data cannot be analysed with Cox regression, as this requires time to event data. Also, the data from the successive follow-ups are not independent, since the probability of an individual reporting LBP in one period is related to the probability in an adjacent period. The Generalising Estimating Equations (GEE) method controls for these problems and has been used in previous studies of risk factors for MSDs (Hamberg-van Reenen *et al.,* 2008; Hoogendoorn *et al.,* 2002a; van den Heuvel *et al.,* 2004). It was therefore chosen as a suitable type of analysis.

4.4.4 Recasting of existing questions in the baseline questionnaire

The baseline worker survey used by Liberty Mutual sought data on potential confounders such as age, height, weight, smoking, exercise levels, back belt usage, vehicle usage and previous LBP. This was modified in various ways with the aim of adding items but allowing meaningful comparisons of common items (Appendix 1). Firstly, items were edited to reflect differences between the USA and the UK. Thus, a question about workers compensation claims was replaced by one about the effect of LBP on work in the previous 12 months. In a question on exercise, references to bowling and softball as examples of team sports were replaced by a reference to football. Because a specific decision had been made to exclude women who were already pregnant or had recently had a baby, a question was added asking about this.

A layout for the questionnaire was chosen that meant that the whole questionnaire could be printed double sided on an A3 sheet and folded to produce an A4 booklet. In the final version, the top of the first page had an HSL logo, the survey title, and a header saying “Confidential: Return to HSL or HSL staff only”. It also included a greyed out box for a reference number to be added by the study administrators. At the bottom of each page, the foot included a revision number and date for the questionnaire, a page number and the HSL job number.

Below the main heading, spaces were included for the subjects to name the firm they worked for, and to give contact details and the date of completion. The next section had a heading of “PERSONAL DETAILS” and asked for basic demographic data: Gender, date of birth, weight and height and handedness. The second section, which took up the remainder of the first page, was headed “ABOUT YOUR JOB” and asked what the job was, and the area/line/cell the respondent worked in. It asked when they had started working for that employer, the average weekly hours worked, the normal working hours and the shift pattern.

The next question proved to be extremely problematic. In the Liberty Mutual protocol it had asked for the “total percent of the day spent doing” “Lifting”, “Lowering”, “Pushing”, “Pulling”, “Holding” and “Carrying”. Initially this was unchanged, but it was clear from early responses that this was ambiguous as some respondents put 100% against each category but some put 16% (i.e., one sixth of the day) against each of the six categories. It was therefore clear that the data from this question could not be analysed, as the responses did not represent in any way the exposure to manual handling of the individual. The final version asked respondents to list tasks that they did regularly that involved these six types of manual handling actions and to say how long they spent on these tasks on each normal day. This was used as a means of cross-checking the tasks identified as part of the on-site job analysis.

The final questions in the ABOUT YOUR JOB section asked about time spent travelling to and from work in a vehicle and about the experience of LBP in the previous 12 months. The section at the top of the second page was titled “ABOUT YOU” and asked about exercise, smoking, back belt use, and (for women only) pregnancy / recent child birth.

4.4.5 Addition of a baseline measure of musculoskeletal trouble

A modification of the short form of the HSE version of the NMQ (Dickinson *et al.,* 1992) was added to the survey questionnaire (Appendix 1). This allowed a baseline cross-sectional indicator of the levels of musculoskeletal trouble being experienced and a retrospective measure of this trouble over the previous three months. These measures were chosen to allow the predictive models to be developed to control confounding due to pre-existing levels of musculoskeletal trouble.

The modifications to the NMQ involved, firstly, changing the twelve month prevalence period to three months because of evidence (Ørhede, 1994) that reporting rates for these periods are effectively identical. The second major modification was the addition of questions on the work-relatedness of the trouble experienced in the previous three months. The shorter, three-month, period reduces the period over which the respondent has to recall trouble, thereby increasing the reliability. The seven-day prevalence period allowed reporting of recent or current trouble and the data from it can be used as a high approximation of point prevalence, i.e., rates of current trouble. “Trouble” is defined on the questionnaire as “ache, pain, discomfort, numbness, tingling, or pins and needles”. Disability due to this trouble was assessed by asking if the trouble had, in the previous three months, prevented the respondent “carrying out normal activities (e.g., job, housework, hobbies).”

The explanatory notes and diagram illustrating the body parts took up the bottom part of the second page of the questionnaire and the NMQ itself took the whole of the third page.

4.4.6 Addition of a questionnaire to assess psychosocial factors

The original Liberty Mutual project protocol concentrated on physical risk factors and did not attempt to control for potential psychosocial confounders which are increasingly being recognised (Davis and Heaney, 2000; Bongers *et al.,* 1993) as one of the main determinants of when work absence results from LBP. There has been considerable consideration of the relationship between psychosocial factors and MSDs (Bartys *et al.,* 2005; Hoogendoorn *et al.,* 2002b; Hoogendoorn *et al.,* 2001; Hemingway *et al.*, 1995; Hoogendoorn *et al.,* 1999; Hoogendoorn *et al.,* 2000a).

Since the original study design was produced, Dempsey (1997) wrote that psychosocial variables should be studied further, "in future epidemiological studies of work-related LBDs". Linton and Skevington (1999) warned that the results of epidemiological studies using psychosocial variables need great caution in interpretation with important consideration being the dangers of poorly defined variables and consequent overlap between them. They went so far as to recommend making bold attempts in study design and timid claims in analysis.

Davis and Heaney (2000) strongly made the case that both biomechanical and psychosocial data must be collected in any study of LBP to prevent the effects of the two factors on the reporting of LBP and lost time being confounded. They described a scoring system for methodological rigor for assessing the quality of studies of work-related LBP (Table 16). The maximum score they gave to any previous study was 9 / 12. The original Liberty Mutual protocol obtained a score of 8 / 12. The addition in the revised protocol (the features of which are emphasised in Table 16) of a suitable method of psychosocial assessment brought this to 11 / 12.

Table 16 Summary assessment of methodological rigor for studies examining the relationship between LBP and biomechanical and / or psychosocial issues

Methodological scoring	*Controlling for confounders*	*Timing of exposure measurement*	*Biomechanical assessment*	*Psychosocial assessment*
0	None	Cross-sectional study with retrospective measurement of LBP[1]	None	None
1	Demographic variables	Cross-sectional with concurrent measurement of LBP and exposure[2]	Single question measures	Single item questions
2	Biomechanical and / or psychosocial variables	**Prospective study**	Multiple question measures	Multiple item scales with low internal consistency
3	**Demographic and biomechanical and / or psychosocial variables**	Prospective study with multiple measures of exposure[3]	**Validated non-self-report measures**[4]	**Multiple item scales with adequate internal consistency (Cronbach's α ≥ 0.7)**[5]

(1) Provided by baseline measurement of three month prevalence with the NMQ.

(2) Measurement of weekly prevalence with the NMQ provided an approximate measure of point prevalence.

(3) The exposure was measured at baseline and was required to stay constant. Thus, subjects were treated as dropouts if they reported that they had changed job or that the job had been redesigned. It could be argued that this is equivalent to making multiple measures of exposure.

(4) Actual load measurements in the workplace

(5) The psychosocial scales described below.

A suitable psychosocial factors questionnaire known as the "PAK" that had been developed in Sweden (Johansson and Rubenowitz, 1994; Hanse, 2002; Larsman *et al.,* 2007) was identified. This had 25 items evenly spread between five scales with acceptable internal consistencies. The five factors covered by the questionnaire were:

- Influence on and control over work;
- Supervisor climate;
- Stimulus from the work itself;
- Relations with fellow workers;
- Psychological work load.

Engstrom *et al.* (1999) grouped the five factors into three dimensions which they linked to the three fundamental dimensions "which should be satisfied at work to meet the person's psychological needs (Karasek and Theorell, 1990)". These dimensions are often described as "Demands", "Control" and "Support" with the result that the theoretical model that links them with health outcomes is often described as the "demands-control-support model" (Theorell, 1996).

- Factors 1 and 3 were grouped as "Decision latitude", i.e., Control.
- Factors 2 and 4 were grouped as "Social support at work", i.e., Support.
- Factor 5 formed the dimension "Psychological workload", i.e., Demands.

The descriptions of the scale items provided by Johansson and Rubenowitz (1994) and Engstrom *et al.* (1999) appeared to be abbreviated translations of the original Swedish and were not suitable for immediate use. Therefore, the scale items were revised while attempting to preserve the underlying concepts. The five-point response scale with verbal anchors only at the extremes was retained, but the anchors were changed to "Strongly disagree" = 1 and "Strongly agree" = 5. Abbreviated items were expanded into full statements and the phrasing of all statements was revised to reflect the change in the anchors. Where the original items referred to multiple concepts, they were simplified so that each item referred only to a single characteristic. Because of evidence (Boocock and Weyman, 1998) that management commitment to health and safety is a crucial factor affecting reporting rates, a sixth scale was constructed to test for this factor. To maintain consistency, this also consisted of five items.

In a pilot study of the usability and reliability of the questionnaire, questionnaires were completed by 22 males working on two construction sites and 17 females employed in a plastics factory. The construction workers were largely carpenters, but also included bricklayers and plasterers. The questionnaire was completed within 10 minutes by all recipients. Reliability analysis of the six scales gave the results in Table 17.

Table 17 Results of reliability analysis of a pilot study of the psychosocial questionnaire

Scale number	*Scale name*	*Scale mean*	*SD*	*Variables*	*No of cases*	*Reliability (Cronbach's α)*
1	Influence on and control over work	15.914	4.112	5	35	0.7596
2	Supervisor climate	17.263	4.403	5	38	0.8660
3	Stimulus from the work itself	17.703	4.551	5	37	0.8617
4	Relations with fellow workers	19.949	4.217	5	39	0.9005
5	Psychological work load	15.472	3.813	5	36	0.7388
6	Management commitment to health and safety	16.718	4.801	5	39	0.8443

All of the reliabilities obtained were greater than the figure of 0.7 specified by Davis and Heaney (2000) so the scales were accepted for use in the study as having adequate internal consistency. Also, the reliabilities of the first five scales compared favourably to the values reported by Johansson and Rubenowitz (1994) and Engstrom *et al.* (1999) (Table 18).

Table 18 Comparison of reliabilities with previous studies

	N	*Influence on and control over work*	*Supervisor climate*	*Stimulus from the work itself*	*Relations with fellow workers*	*Psychological work load*
Pilot study	39	0.76	0.87	0.86	0.90	0.74
Johansson and Rubenowitz (1994)	9333	0.65	0.84	0.85	0.82	0.83
Engstrom *et al.* (1999)	97	0.69	0.83	0.88	0.67	0.87

The psychosocial questionnaire was headed "Work characteristics" and formed the back page of the four-page questionnaire.

4.5 SELECTION CRITERIA FOR JOBS

The study design required that a variety of job types with different manual handling demands be studied, not just very stressful jobs. The initial criteria for including jobs in the study were:

- Manual handling had to occur as a regular daily activity, with each worker performing at least 25 lifts / lowers per day.
- Jobs had to be expected to continue in their existing form for least 18 months.
- Jobs were to have at least 10 workers performing them, even if not all of them were included in the study. (This requirement was dropped when recruitment began.)
- Jobs were not to vary with the time of year or be seasonal or have job rotation periods of more than one week.

- Jobs were to be mostly the same from day to day so that the data collected were a reasonable representation of what the worker did every day.
- It was preferable that jobs should include few component tasks so that they involve only a few distinct manual handling operations.
- Jobs were not to involve substantial vehicle driving.
- Jobs were not to involve handling of people.
- Individual manual handling operations had to be carried out by either a single person or, at most, a team of two people.

Selection criteria for jobs were deliberately rigorous to ensure that high quality data were obtained and to help control confounders. Jobs had to involve regular manual handling without too much variability and had to be likely to stay the same for the 18 months of the follow-up. Subjects had to expect to stay in the job for the 18 months, and be willing to fill in the baseline questionnaire and to complete a follow-up questionnaire every three months for 18 months.

4.6 TYPES OF JOBS

Four categories of job permitted to enter the study had been identified by Dempsey (1998) in order to increase the scope of the study. The "standard jobs" category was the ideal.

4.6.1 Standard jobs

These are jobs in which the manual handling tasks that are performed from day to day are identical or very similar, i.e., the weight, hand height, etc., for each task are quite stable. Examples include assembly tasks involving lifting or lowering during each cycle, and palletising tasks of the same or similar products, etc.

4.6.2 Variable weight jobs

These are jobs in which the manual handling tasks performed remain relatively stable, but the weight changes. Detailed information on the way the weight varies is required. For example, a worker in a machine shop may operate a certain type of metal removing machine (such as a lathe or mill) approximately once every five minutes. The process may require the worker to lift the stock into and out of the machine, but the weight will vary depending upon the product.

4.6.3 Warehousing / complex jobs

These are jobs that involve many different types of lifts / lowers and different loads. Other than exclusively warehouse picking jobs, there are situations in which workers perform very large numbers of distinct manual handling tasks ("complex" jobs). An example would be unloading trucks (assuming the same worker is not the driver, since significant driving excludes a job).

4.6.4 Job rotation schemes

Situations where workers rotate between two or more jobs were acceptable for the study if the rotation schedule was regular and on a daily or weekly basis rather than a monthly or seasonal basis. At least one of the jobs in a rotating schedule had to have a significant manual handling component and information was required on each of the rotations.

4.7 SUBJECT SELECTION

Both men and women employed in the jobs that qualified for the study were asked to participate. No age limits or health status restrictions were imposed except that women who were pregnant or who had had a baby in the previous six months were excluded, since pregnancy itself can cause LBP. Individuals who took part needed to:

- Be full-time employees;
- Have at least one week of experience in the job;
- Expect to stay in the job for the following 18 months.

4.8 CASE DEFINITIONS

The outcome of major interest in this study was LBP sufficiently severe to cause economic costs due to workers taking time off work. However, due to the complexity of the concepts related to LBP and disability due to LBP (Leamon, 1994b), and the complex ways in which it can affect work, several case definitions were used. These were:

- Incident cases of LBP that did not affect the person's attendance at work;
- Incident cases of LBP that resulted in the person working restricted hours or being placed on light duty;
- Incident cases of LBP that resulted in the person taking time off work;
- Incident cases of injury at work that did not affect the person's attendance at work;
- Incident cases of injury at work that resulted in the person working restricted hours or being placed on light duty;
- Incident cases of injury at work that resulted in the person taking time off work;
- Prevalent cases of self-reported LBP in the 12 months prior to entry to the study that did not affect the person's ability to carry out their work;
- Prevalent cases of self-reported LBP in the 12 months prior to entry to the study that resulted in the person working restricted hours or being placed on light duty;
- Prevalent cases of self-reported LBP in the 12 months prior to entry to the study that resulted in the person taking time off work;
- Prevalent cases, in nine body parts in the three months prior to entry to the study, of self-reported musculoskeletal trouble as defined by the HSE version of the Nordic Musculoskeletal Questionnaire (NMQ) (Dickinson *et al.,* 1992);
- Prevalent cases, in nine body parts in the seven days prior to entry to the study, of self-reported musculoskeletal trouble as defined by the NMQ;
- Prevalent cases, in nine body parts in the three months prior to entry to the study, of self-reported disability caused by musculoskeletal trouble as defined on the NMQ;
- Prevalent cases, in nine body parts in the three months prior to entry to the study, of self-reported musculoskeletal trouble, as defined on the NMQ, reported to be caused or made worse by the respondent's job.

Dionne (1999) noted that many definitions of LBP have been used by different studies. For the purposes of this study, the term LBP was not specifically defined but was consistently used in the initial section of the baseline questionnaire and the follow-up questionnaires. Because the NMQ was used in the baseline questionnaire, the accompanying diagram (Dickinson *et al.,*

1992) was used to define the nine body areas, one of which was labelled “Lower back (small of back)”. This will have indicated to subjects at baseline the area that was meant and that the “hips/thighs/buttocks” formed a separate area. Unlike Dionne (1999), no attempt was made to include sciatic pain or cruralgia in the definition. No attempt was made to use an anatomically precise definition such as “between the gluteal folds inferiorly and the line of the 12th rib superiorly”. Such a description would not have been meaningful to many of the participants and would have required a separate diagram to explain it. It was felt that most people have a clear idea of where their low back is and further definition was unnecessary.

As both the baseline questionnaire and the follow-up questionnaires asked for reports of LBP, no attempt was made during data collection to distinguish between completely new reports of LBP, prevalent cases or recurrent cases. As the lifetime incidence of LBP is estimated to be between 50% and 80%, and as it is known that many individuals forget resolved episodes, it would not have been practical to attempt to recruit only subjects who had never had an episode of LBP. Instead, questions in the baseline questionnaire about LBP experience (in the previous 12 months, three months and seven days) and its severity in the previous 12 months and three months provided data that could be used to adjust the predictive models that were to be developed.

Moreover, as the main outcome of interest was work loss due to LBP, the issue was not whether an individual had a history of LBP but what could predict an episode of time off work. Therefore, in the context of the workplace, a previous history of LBP is a potentially important predictor of work loss.

Therefore, for the purposes of the study, an incident episode of work loss was defined as one that began during the follow-up, whether new or recurrent. By definition, as the subjects were recruited at work, none were off work at baseline, so all were free of work loss at baseline.

5 EXECUTION OF THE PROJECT PROTOCOL

5.1 ETHICAL APPROVAL, SURVEY CONTROL APPROVAL AND INFORMED CONSENT

The revisions to the study protocol, and the associated information sheets for companies and individuals, consent forms and questionnaires were approved by the HSE Research Ethics Committee (ETHCOM/REG/98/12) in May 2001. Survey Control approval was obtained from the HSE Survey Control Liaison Officer in April 2001.

Participating firms and individuals gave informed consent to participation and to the use of photographs of individuals and processes. The information sheets, consent forms and questionnaires are reproduced in Appendix 1.

5.2 RECRUITMENT OF FIRMS AND SUBJECTS

Initially, HSE inspectors were asked to suggest firms that might be willing to participate. Other firms were identified through HSE databases of firms, particularly from the manufacturing sector. Some firms were identified through contact with industry bodies. Initial contact was by phone to establish whether a company had suitable jobs. They were then sent the information sheet for companies by email to allow them to consider whether they wished to take part. Decisions on recruitment of companies were often protracted when companies considered participation at regular health and safety meetings or board meetings.

Once a company indicated willingness to participate, an initial visit was paid to it in order to view jobs that the firm thought suitable. This provided an opportunity for face-to-face discussion of the project requirements with management and, where possible, union and/or safety representatives. If the firm was still willing to take part, a date was then agreed for a return visit to recruit individual subjects and make measurements of the jobs. Management were asked, where possible, to distribute information to workers in suitable jobs before the main visit so they could consider whether to participate. Recruitment of firms began in mid 2001, with the first subjects recruited in January 2002. 515 subjects were recruited from 19 plants belonging to 12 firms before subject recruitment ended in July 2003.

In an attempt to reduce the effort required for recruitment of subjects, the initial target was to use only firms with at least 50 workers involved in suitable jobs and at least 10 individuals employed in each job. These requirements were dropped immediately recruitment began as it was realised that very few employers had large numbers doing identical work.

5.3 BASELINE DATA COLLECTION

Subjects completed a consent form after reading the participant information sheet (both in Appendix 1). The form asked if they would be willing to be videoed or photographed. It was emphasised that it was not necessary to video all participants. They were asked to complete the baseline questionnaire, and if not already completed, the consent form, in work time. This was usually done with a group of subjects, often during a planned or natural break, or at the start of the work shift. This allowed subjects to ask questions about the study and the questionnaire. The HSL researcher checked that all questions had been completed on the form and, if not, handed it straight back to the subject with a request to complete the missing items, thus reducing the amount of missing data to a minimum. The questionnaire was marked as “Confidential” and had a heading or watermark stating that it should only be returned to HSL staff or HSL.

Where workers were on night shifts, questionnaires were sometimes left with them at the start of the shift for completion during the shift and they were given return envelopes to ensure that the responses remained confidential. On the envelopes was an HSL FREEPOST address that had been created for the study. Where possible, the completed questionnaires were collected the following day from the individuals concerned. Otherwise, arrangements were made for them to be returned via union or safety representatives, or management. Questionnaires and return envelopes were occasionally left for subjects who had filled in a consent form, but were unavailable at the time of the visit. These, and a number left directly with individuals were returned by post, but it was known that response rates would be lower when this was the only possible method, so it was avoided if at all possible.

The baseline questionnaire started by recording the firm the person worked for, the name and contact details of the individual, including postal address and home and mobile phone numbers, and the completion date, which was treated as the entry date to the study. The questionnaires could not be anonymous due to the need for repeated contact with the subjects and the need to link responses on the follow-up questionnaires to the baseline questionnaire and job measurements. Subject numbers were allocated sequentially as groups of subjects were recruited from the participating firms. They were written on the baseline questionnaires and printed on each follow-up questionnaire.

Baseline measurements were made of the job during the second visit to the workplace. Video was used to record the job and to allow frequency of lift to be measured off-site. Dimensions required for the NIOSH analysis were measured and recorded on a PDA or on paper or verbally and / or visually on video for later extraction. Weights were recorded either from direct weighing of the item on a set of calibrated electronic bathroom scales or directly from markings on the object. Where possible, weight information was taken from company records.

5.4 FOLLOW-UP OF SUBJECTS

5.4.1 Postal questionnaires

Follow-up questionnaires were sent out by post. Template letters were created for each follow-up. A mail merge file was also created containing name, address and job details for each subject. All of these files were password protected. The merge file also contained the date the subject entered the study and the six dates that each individual was due to be followed up. Every three months from the date of entry to the study of a group of workers, a mail merge was used to produce covering letters and one page questionnaires (see Appendix 1) that were posted to the contact addresses of the subjects.

The covering letter with the follow-up questionnaire reminded the subject that he or she had agreed to complete follow-up questionnaires every three months for 18 months and stated which follow-up it was. The first section of the questionnaire asked the individual to check their contact details. The second asked if he or she was still working in the job and work area and for the company stated on the baseline questionnaire. The third section asked if he or she had experienced LBP since the date of the previous response and if so, three options were offered:

- “Work not affected”;
- “Put on light duties / restricted hours”;
- “Taken time off work”.

Start and end dates were requested for the last two options.

The fourth section asked if the subject had been injured at work in the same period and offered the same response options, including asking for start and end dates for light duties or time off. For the "Work not affected" response, it also asked for the date of injury. Additional questions asked for the type of injury and the body part injured.

The follow-up questionnaire had space for a signature and a date of completion to validate the data and to "fix" the response in time, thus avoiding the ambiguity that could arise if there was a gap between completing the form and posting it. Where the date was missing the date of the postmark on the reply envelope was inserted.

Every questionnaire sent was accompanied by a return envelope with the study FREEPOST address on to provide the subjects with a cost-free method of returning the follow-up questionnaires.

Questionnaires were date stamped as they were received. As they were received, the merge file was updated with the completion date of each follow-up form returned. This was the date used in the subsequent follow-up. This permitted gaps in follow-up to be filled and prevented follow-up periods overlapping. Thus, if a subject entered the study on 10 January the first follow-up letter was sent on or about 10 April, asking if problems had been experienced since 10 January. The second follow-up was sent on or about 10 July whatever the date of the response to the first follow-up.

- If no response had been received, it asked about problems since 10 January.
- If a response dated 12 April had been received, it asked about problems since 12 April
- If a response dated 12 May had been received, (e.g. after a reminder letter had been sent), the second follow-up asked about problems since 12 May.

In a very few cases where a response to a previous follow-up was received when the next follow-up was due, it was treated as being the later follow-up.

The merge file for generating follow-up letters was maintained through a word-processor program. The address and job information fields were updated whenever information was obtained about a subject changing address or job. The planned follow-up dates were updated with the actual follow-up dates. A field was included to indicate whether a subject had dropped out of the study. Part way through the follow-up it was found that errors were occurring due to the merge file not having been kept fully up to date. Therefore, a checklist was printed on a label and attached to each questionnaire when it was received and used to indicate when data had been entered in the correct files.

The question about whether a subject was still employed in the same job presented multiple options for reasons for changing job and asked for information about the new job and the date of changing / leaving the job. An "other" option allowed the recording of cases not in the original list, including where a subject informed us that he or she did not wish to continue in the study or where subjects were lost to follow-up, e.g. when follow-up letters were returned as undelivered. The question deliberately did not ask if the subject wished to continue in the study but if one was returned a questionnaire stating a wish to dropout of the study, this was respected. If a subject did not return a questionnaire then that individual was still included in the subsequent follow-ups.

Early in recruitment, and on advice from Patrick Dempsey, the decision was made to encourage participation by offering subjects a T-shirt with a logo based upon diagrams of safe lifting technique. The subjects recruited earlier were offered a T-shirt when contacted for the next follow-up. Once recruitment had finished, offers of spare T-shirts were used at intervals as inducements to return follow-up questionnaires.

The nature of the jobs, which often included complex shift patterns, meant that any attempt to carry out follow-up solely by phone would have been ineffective. The primary method chosen was by post and this had the advantage of generating traceable follow-up forms, thus helping validate the data. Follow-up by e-mail was not attempted, as this would have required subjects to have e-mail addresses and suitable e-mail software that would allow them to digitally sign their responses. It was assumed that many subjects would not be computer literate or have access to e-mail.

5.4.2 Telephone / postal reminders

Non-responders were reminded up to three times. Where possible, the reminder was done by phone. If a subject could not be contacted in person, a message was left with the person answering the phone or on an answer-phone or voicemail service if available. Where no phone number was available or phone contact could not be made, a reminder letter was sent. Where appropriate, the questions were asked over the phone and the answers recorded on a copy of the follow-up questionnaire. Each follow-up questionnaire was identified by the number of the follow-up and the subject number and had the date of sending. Reminder letters were identified by an (R) after the date. They were filed in subject number within follow-ups. Data were entered immediately into the contacts database to ensure that further follow-ups were not made to individuals who had returned the questionnaire. Data for the main database were entered either immediately or soon afterwards.

The first reminders were scheduled for two weeks after the initial follow-up letters were sent, and the second and third reminders were scheduled at weekly intervals after that. These dates were largely adhered to, with only a small proportion being sent out more than a few days late. The spreadsheet was constructed to flag overdue reminders. Inevitably, a small number of errors were made, mostly due to the merge file used to produce the follow-up or reminder letters not being updated.

5.4.3 Company follow-up

To provide a secondary source of job change / absence data, each company was contacted to ask about job changes absences due to LBP and injuries at work that they had records for the individuals participating in the study. This was done for two periods: the first nine months and the final nine months of the follow-up. Not all companies responded to these requests. These data were reconciled with the follow-up data from individuals. Where there were discrepancies judgements were made as to which was more reliable, taking into account the tendency of company responses to fail to answer some questions. This proved to be an invaluable means of identifying individuals who had changed job but had failed to respond to follow-up questionnaires.

5.4.4 RIDDOR reports

In early 2005, the HSE FOCUS and ICC databases of over 3 day absences reported under the RIDDOR regulations were searched by name and study dates for all participants. This resulted in a number of reports being retrieved that allowed some reports of LBP received from individuals to be identified as being not due to manual handling (e.g. due to a vehicle impact). It was noted that many over 3 day absences notified by individuals were not reported under RIDDOR. The ICC database was searched again in early 2008 to check for later reports.

5.4.5 Missing follow-up data

Subjects from whom no LBP or injury follow-up data were obtained were recorded as having a single day in the study.

5.5 DATA HANDLING

5.5.1 Spreadsheet databases

To ensure confidentiality and security of the personal data at the analysis stage, two password-protected spreadsheet databases were created with multiple linked sheets.

The “Contacts” database contained subject numbers, names, contact details, consent information, entry and follow-up dates, whether reminders were due, and whether the subject had dropped out from the study. The follow-ups were labelled FU1 to FU6 and each had a separate sheet within the database. The subject reference number appeared in the left hand margin of each spreadsheet so the record for each subject appeared on a single row with variable names visible across the top of the spreadsheet. Each follow-up sheet had a column to indicate: if a subject was a new dropout; due dates; the actual dates that follow-up letters were sent; the dates of the replies, and the dates they were actually received. Other columns flagged whether a reminder was due and the reminder type (letter/phone or letter only). Columns were provided to enter the dates the three reminders were made, each with a column for notes as to the outcome of the reminder (e.g. “Left message on answer phone”). A flag indicated whether a reminder was overdue and another indicated whether the subject had dropped out at this or a previous follow-up. Another sheet summarised the status of each subject across all follow-ups, indicating where replies had been received, where a subject had dropped out, where replies had not been received and where missing periods had been covered by later replies. Days and weeks of follow-up were calculated. Where a subject was lost to follow-up the date of the last reply was used as the termination date.

A summary sheet gave an overview of progress across the six follow-ups. It indicated:

- The numbers of questionnaires sent, replies received and replies outstanding.
- The number of subjects who had confirmed they were still in the study.
- The number of new dropouts that had occurred at each follow-up
- Cumulative totals and percentages were also calculated.
- Checksums and check sums of squares were calculated using the subject reference numbers of the subjects who had responded at each follow-up. These values were used to ensure consistency with the main database.

The main database contained subject reference numbers, data from the baseline questionnaire and data from each follow-up questionnaire. In each case, data from each subject were entered on a single row of the spreadsheet. Multiple sheets were used to keep track of the different stages of the follow-up and subject numbers were carried across to ensure easy identification. Column titles were always visible at the top of the screen and subject numbers were always visible on the left hand side to ensure easy navigation. Check sums and other error-trapping tests were calculated in the spreadsheets to help the identification of keying errors and out of range data.

The main database also had a summary sheet to indicate the number of responses received and the numbers of each type of response (e.g. lost time due to LBP). Like the summary sheet in the contacts database, it calculated sums and sums of squares, and regular comparisons were made to ensure that data from each questionnaire were entered correctly in both spreadsheets. It therefore permitted identification of cases where data had been entered against the incorrect subject number (the wrong row).

Missing data were explicitly coded in each question. Durations in the study (days of follow-up) before becoming a case or dropout were calculated. Criteria were defined in the spreadsheet for determining if a subject was a case or a dropout based on the response to the question about still being in the same job. If a subject changed to another job at the same firm that was also included in the study he or she was not treated as a dropout and follow-up continued. A field was included in the spreadsheet to record this fact.

The main spreadsheet was used to calculate derivative variables such as Body Mass Index (BMI) and descriptive statistics for basic analysis of the data. The numbers of reports of LBP and of lost time due to LBP were calculated for each follow-up and cumulatively across the previous follow-ups.

The contacts and main databases were updated throughout the study. This was usually done immediately for the contacts database because of the need for accurate information for reminding non-responders.

5.5.2 Checking of follow-up data

The nature of the follow-up with repeated questionnaires returned by subjects meant that some episodes of lost time crossed boundaries between questionnaires. Therefore all episodes of lost time recorded in the database were checked manually against the completed questionnaires and multiple reports of the same event were reconciled.

5.6 REDUCTION OF COLLECTED TASK DATA

5.6.1 Calculation of Lifting Index

The spreadsheet file with subject data had a sheet added for analysis of task data to calculate individual multipliers for each task and hence outcome measures such as the STLI and CLI. A block was created for each job identified. Within this block there were multiple lines, with one line being used for each task that contributed to a job. Columns in the spreadsheet were set up for task parameters and to calculate multipliers for both the 1981 and 1991 equations within each line. Lookup tables were created for calculating the Frequency and Coupling Multipliers (FM and CM). Frequency was obtained from video of the task by counting the number of occurrences observed and the duration of the observation. Linear interpolation was used to calculate values of FM for frequencies that were not in the lookup table. The multipliers were then used to calculate the 1981 AL and 1991 RWL and hence the 1981 LI and 1991 LI.

To facilitate future use of the data to test the ability of the MAC to predict lost time due to LBP, linked sheets were set up to convert the parameters recorded for the NIOSH equation into MAC colour codes and hence into MAC scores. As the MAC requires additional parameters, such as Side bending angle and Floor surface, these were also entered into the task analysis spreadsheet. Where the task included carrying or team handling this was also coded. Columns were also included to record One-handed handling and the carrying out of Additional Tasks.

The coding of these additional data permitted the calculation of the Risk Index for the EN equation. Since the ISO equation does not define any index, the NIOSH approach was applied to it so that a Lifting Index for the adult population, ISOLIAdult was defined as m/m_{ref}.

The spreadsheet was also used to calculate the STRWL, FIRWL, STLI and FILI for each task. (The STLI for a task is identical to the LI for that task.) By using the data from all the tasks included in the job, the spreadsheet was also used to find the task with the maximum STLI and then to sort the tasks into decreasing order of severity as measured by STLI and hence to calculate the CLI for the job. The CLI for each job was then assigned to each individual within that job so that the analysis could relate the exposure to the outcome.

5.6.2 Assessment of individual parameters

At the stage of setting up the spreadsheet to calculate the CLI, it was realised that it is only meaningful to attempt to predict LBP outcomes from a composite exposure index, such as the CLI, that takes into account all exposure to manual handling. In the special case that an individual is only exposed to a single lifting task the CLI is equal to the STLI. Moreover, in this case it is possible to relate the individual parameters of the lift to the outcome as a one-to-one correspondence can be established between exposure to (for example) horizontal distance of the load and risk of injury. However, once a worker is exposed to more than one lifting task there are then multiple values of each parameter and each risk index.

It was therefore realised that the aims of testing the ability of individual variables and multipliers, as set out in Table 13 in Section 4.3, could not be achieved since almost all jobs included in the study had more than one lifting operation included. It was therefore decided that in addition to the CLI for each job, the maximum STLI for each job should also be used as a predictor since, according to the 1991 equation, it represents the worst aspect of the job.

It was then decided that the decision to use the maximum STLI for a job as a predictor made it reasonable to use the variables that contribute to that value as predictors. It must be borne in mind that the combining of variables through multipliers means that the extreme value of the STLI might be due to an extreme value of a single parameter such as frequency and that the maximum values of other parameters could be spread across a number of other tasks within the job. The issue of how to analyse individual parameters therefore needs further consideration. Some kind of frequency weighting may need to be considered. In addition, the issue of whether a particular parameter should be considered inherently safe below a suitable threshold should be looked at.

5.7 MULTI-TASK EXPOSURES

5.7.1 Lack of defined methods of assessing multi-task exposure for other assessment methods

From identifying the need for a single composite index as a predictor of LBP, it was realised that the lack of such composite indices for the ISO and EN equations meant that they could not be tested as predictors at this stage. In theory, the approach taken by the NIOSH CLI could be applied. This has not yet been tried.

5.7.2 Short duration sequential tasks

Strictly, the CLI is intended to analyse tasks where the load or the location of the load vary from lift to lift. Examples given in the Applications Manual (Waters *et al.,* 1994) include a depalletising operation (Example 7), a task requiring stacking cans to multiple shelves (Example 8) and a packaging and palletising operation (Example 9). However, many tasks can be performed either in an interspersed manner (an item is packaged in a carton and the carton palletised immediately) or in a batch manner (a number of items are packaged in cartons and pushed to a holding area and then the whole batch is palletised).

In the case of Example 8, the bottom shelf might be filled first, then the second, then the third, rather than each shelf having an item added in turn. In this example, the overall handling rate is given as nine lifts per minute, for one hour – three lifts per shelf per minute. If the worker were to choose to spend 20 minutes loading each shelf at nine lifts per minute, then because the total lifting exposure is the same over the course of the hour, the CLI should be the same.

If the tasks are interspersed, the frequency multiplier for each individual task is based on three lifts per minute for one hour. The frequency multiplier for the combination of the three tasks is based on nine lifts per minute for one hour. If the tasks are analysed sequentially, each task is analysed as nine lifts per minute, thereby reducing the value of FM excessively.

In order to ensure that the CLI is correctly calculated the approach adopted was to average the lifting frequency over the hour when the tasks are sequential so that the calculation becomes identical to the calculation when the tasks are interspersed. Thus, nine lifts per minute to Shelf 1 over 20 minutes results in 180 lifts. There then follow 180 lifts to Shelf 2, and 180 lifts to Shelf 3. So, the total duration of lifting is 60 minutes, the total number of lifts is 540 lifts and the total lifting rate is nine lifts per minute, with a mean lifting rate per task of three lifts per minute. Therefore, the STLI values are based on a value of F of three lifts per minute. As each task is added to the CLI calculation, the total frequency, Fsum, increases by three lifts per minute, so is six lifts per minute for two tasks and nine lifts per minute for all three tasks.

5.7.3 Single equivalent values for variable H and variable V tasks

It was realised that a number of tasks varied systematically, in one or both of the horizontal distance, H, and the vertical start or finish height, V. A typical example would be an inspection/stacking task where an item was removed from the outfeed of a machine, examined for defects and then placed on a stack of the product. Once the stack reached a particular height it would be removed, usually by mechanical means such as a fork-lift truck, and the worker would begin building a new stack. One example seen was cupboard doors, typically 20 mm thick, being stacked from a height of approximately 300 mm to 1300 mm.

It was realised that in the circumstance where only one variable varied in the 1991 equation, it would simplify analysis if the varying value of V or H could be replaced by a "Single Equivalent Value" (SEV).

Varying the H parameter (e.g. a series of lifts of objects from the front to the back of a pick slot) affects the HM value. Thus if five lifts were carried out with values of H incrementing each time by, say, 75 mm from 250 mm, to 325, 400, 475 and 550 mm, the CLI can be calculated for the five lifts at varying distances. It should also be possible to find a single value of H at which five lifts at the same overall frequency (so that FM is adjusted correctly) would give the same STLI as the CLI.

This can be done with one of Horigin or Hdest being constant and the other varying. In principle, it would be possible to do this calculation when both Horigin and Hdest are variable, but that level of complexity has not been explored.

In a similar way, it is in theory possible to calculate a Single Equivalent Value for Vorigin or Vdest where one is constant and the other varies. This is slightly more complex than for variable H tasks as not only the VM is affected by variation in V, but also the DM and the CM. Again, the overall frequency must be correctly spread across the lifts at different values of V.

In practice, the complexity of the effect of V means not all situations are solvable for an SEV of V. This is the case when a fixed value of Vdest, in a job where significant control is needed at the destination, is further from the Vneutral value of 750 mm than any of the Vorigin values. In such circumstances, the full CLI calculation must be carried out. Removing the need for significant control at the destination seems to obviate this problem but can result in SEVs outside the actual range between Vorigin and Vdest.

Given a task where both H and V vary (e.g. palletising from a conveyor) it is possible to use the above approaches in a two-stage approach. Since variation in H only affects HM, the SEV for H should be calculated for each layer of the pallet and then the different height layers combined to calculate the SEV for V across the layers. This will allow different stacking patterns in different levels of pallets to be accounted for.

While this process simplifies the analysis by allowing automatic increments of the variable, and gives the correct value of the CLI for the combined task, analysis of a number of tasks has shown that SEVs for H or V can be larger than the maximum individual value of H or V. This is counterintuitive but does not affect the validity of the CLI value obtained.

Further analysis of the equation is needed to clarify exactly what the issues are, but two aspects that should be examined are:

- The effect of the non-linear relationship between F and FM as F is incremented as lifts are combined.
- The use of the maximum STLI value as the base that is incremented according to the change in LI as each task is added. There is therefore no way of reducing the total, so if the maximum value of H gives the maximum STLI, adding tasks can only increase the CLI. Also, for an SEV of a variable H, the only multipliers that vary are HM and FM, and FM will always tend to decrease as tasks are added.

5.7.4 Rotation between jobs and averaging

One approach that is adopted in some workplaces is for a group of workers on a shift to rotate around tasks such as positions on an assembly line during the course of the shift. This can happen at intervals as short as every 20 minutes.

To take account of such systems, as each individual can carry out each lifting task, each must be included in the analysis. The approach taken was similar to that for short duration tasks by calculating the lifting frequency for each task over the whole rotation cycle. The lifting duration must reflect the overall duration of lifting over the rotation. So, if the lifting tasks occur throughout the shift, the duration must be set to 8 hours, even if any particular task by itself would be allocated a duration of 1 hour.

Thus, if six workers are on the line of which three are performing different lifting tasks at any time, the frequency must be adjusted so that the correct average number of each lift per day is assigned to each worker as his exposure. If in 30 minutes 30 lifts were observed at one workstation (1 lift per minute), 15 at another (1 lift per two minutes) and 60 at a third (two lifts per minute), with non-lifting tasks at the other three stations, these must be converted into rates of one lift every six minutes, every twelve minutes and every three minutes respectively before the CLI is calculated.

The 1991 equation is based on the assumption that the task is carried out for a period of up to eight hours. For shorter durations, allowances can be made for recovery periods within the day. It is implicit in this approach that no change is made to the LI when the task is carried out over multiple days. Therefore, the decision was made to account for job rotation that took place over a daily or longer cycle (e.g. weekly) by taking as the overall exposure the simple arithmetic mean of the CLIs for the different rotations.

5.8 SAMPLE SIZE ACHIEVED AT BASELINE AND INCLUDED IN THE LONGITUDINAL ANALYSIS

Subject recruitment began in January 2002. Significant difficulties were experienced in finding firms willing to participate with large numbers of suitable jobs that were expected to stay constant for the duration of the follow-up period. By the end of the summer of 2003, only 515 subjects had been recruited and it appeared that the short to medium-term prospects of finding additional firms to participate were poor. A decision was therefore made to terminate recruitment at that stage in order to control the project timescale. Follow-up of subjects therefore concluded in January 2005.

The off-site conversion of the gathered task data into the form needed for statistical analysis proved to be a highly complex and very labour intensive process due to the level of detail required to characterise the manual handling requirements of a job, particularly when more than one task was carried out by a worker. Because of this, and in the light of power considerations and the relative rates of lost time and reporting of LBP, the longitudinal analyses reported are based on the examination of task data for 367 subject/job combinations. These were spread across 86 jobs. Of these 75 were unique jobs, and another 11 involved job rotation.

Nine subjects in two of the jobs examined were omitted from the analysis by being assigned zero exposure to lifting. Four of these were in a job that was found to be extremely variable and the gathered data were inadequate to characterise it. The remaining five were managers in one firm who carried out little or no manual handling.

Therefore, the analyses are based on the remaining 358 subject-job combinations spread across . Baseline data were analysed for 343 subjects. Another three subjects whose jobs have not been analysed at baseline transferred during the study into jobs that had been analysed and were therefore included in the second job, giving 346 individuals in the longitudinal analysis. The remaining twelve subject-job combinations were due to individuals included at baseline transferring into other jobs included in the study so they were included twice in the analysis.

6 RESULTS OF BASELINE ANALYSIS

6.1 FACTOR STRUCTURE OF PSYCHOSOCIAL QUESTIONNAIRE

The psychosocial (“Work Characteristics”) questionnaire used at baseline (Appendix 1) had been modified from the Swedish original for the purposes of this study (Section 4.4.6). In order to test whether it contained the expected six factors, Confirmatory Factor Analysis was carried out on the data obtained from the 515 subjects. SPSS v14.0 was used to perform Principal Components extraction using the covariance matrix. Initially, eigenvalues greater than 1.0 were extracted. Subsequently, six eigenvalues were extracted to match the expected factor structure. Varimax rotation was used. Missing values were excluded listwise, i.e. all data for those cases were excluded. In the output, coefficient values less than 0.316 were suppressed since they represent low loadings, ($R^2 < 10\%$)

6.1.1 Initial extraction of factors

Descriptive statistics of the responses to the Work Characteristics questions are given in Table 19.

Table 19 Descriptive statistics for psychosocial data (N = 491)

	Mean	*Std. Deviation*		*Mean*	*Std. Deviation*
WC1	3.47	1.323	***WC16***	4.22	.898
WC2	3.44	1.280	***WC17***	3.99	1.098
WC3	2.92	1.438	***WC18***	3.20	1.309
WC4	2.61	1.409	***WC19***	3.36	1.223
WC5	2.26	1.346	***WC20***	3.92	1.083
WC6	3.97	1.150	***WC21***	3.21	1.266
WC7	2.95	1.391	***WC22***	3.39	1.202
WC8	3.23	1.279	***WC23***	3.04	1.255
WC9	3.29	1.248	***WC24***	2.94	1.405
WC10	2.78	1.320	***WC25***	3.40	1.190
WC11	2.77	1.309	***WC26***	3.15	1.389
WC12	2.96	1.349	***WC27***	4.23	1.050
WC13	2.90	1.297	***WC28***	3.67	1.242
WC14	3.07	1.395	***WC29***	2.48	1.314
WC15	3.28	1.223	***WC30***	3.63	1.302

The initial extraction of factors with eigenvalues > 1 (Scree plot in Figure 1) resulted in seven factors. The total variance explained by the model was 64.0%. Percentages of variance accounted for by each factor ranged between 11.3% and 5.1% (Table 20).

The rotated component matrix (Table 21) showed a good match with the expected factor structure. The most significant deviation was that WC1 – WC5 were split across the last two factors extracted, with WC2 and WC3 loading on both factors. WC15 cross-loaded (i.e., had more than 10% of variance in common) onto two other factors; WC10, WC18 and WC24 each cross-loaded onto one other factor. None of the cross-loadings had r values > 0.375 (14.1% of variance).

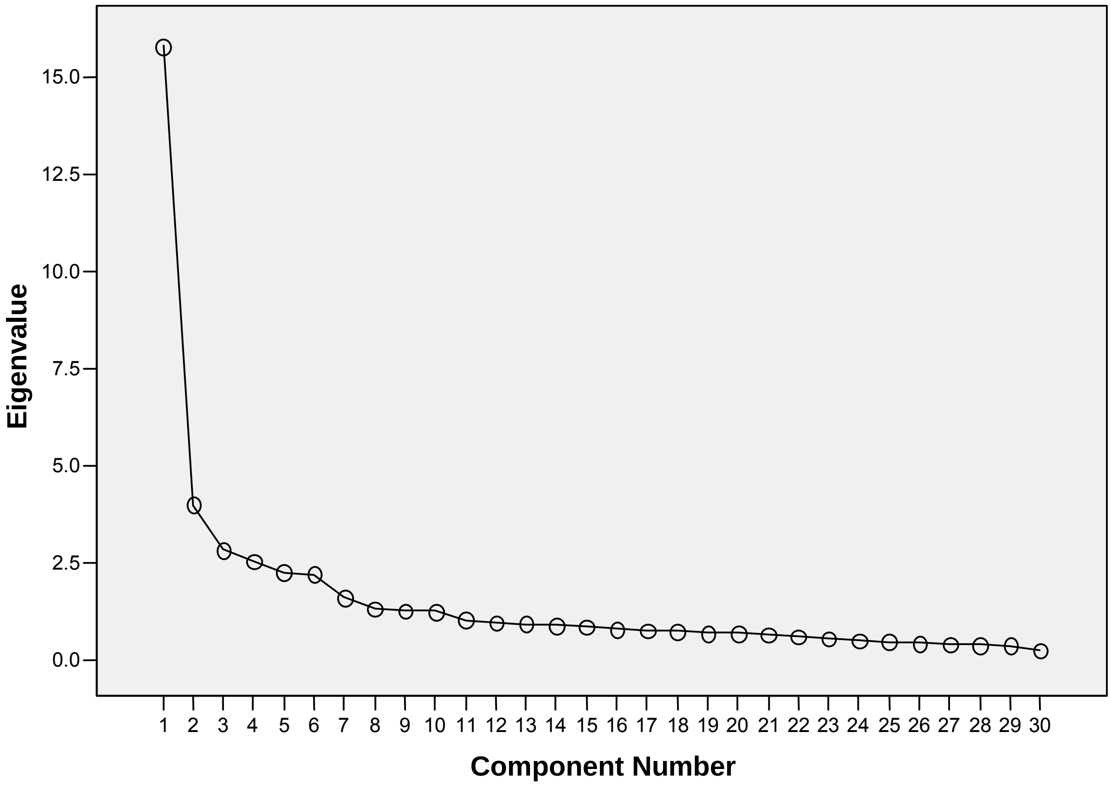


Figure 1 Scree plot for initial extraction of psychosocial factors

Table 20 Total variance explained after rescaling initial extraction

Component	*Rotation Sums of Squared Loadings*		
	Total	*% variance*	*Cumulative % variance*
1	3.386	11.29	11.29
2	3.205	10.68	21.97
3	3.011	10.04	32.01
4	3.010	10.03	42.04
5	2.999	10.00	52.03
6	2.049	6.83	58.86
7	1.534	5.11	63.98

Extraction Method: Principal Component Analysis.

Table 21 Rotated component matrix after rescaling for initial extraction of psychosocial factors

	1	*2*	*3*	*4*	*5*	*6*	*7*
WC1							.857
WC2						.330	.700
WC3						.652	.354
WC4						.749	
WC5						.792	
WC6			.653				
WC7			.773				
WC8			.803				
WC9			.748				
WC10	.369		.450				
WC11					.774		
WC12					.786		
WC13					.723		
WC14					.633		
WC15		.336		.378	.526		
WC16				.748			
WC17				.750			
WC18		.375		.629			
WC19				.589			
WC20				.667			
WC21		.756					
WC22		.705					
WC23		.682					
WC24		.634			.318		
WC25		.703					
WC26	.822						
WC27	.570						
WC28	.778						
WC29	.664						
WC30	.710						

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

6.1.2 Extraction of six factors

Forcing the extraction of the expected six factors (Scree plot in Figure 2) resulted in the total variance explained by the model being reduced to 60.8%. Percentages of variance accounted for by each factor ranged between 11.4% and 8.3% (Table 22).

The rotated component matrix (Table 23) matched the expected factor structure with each variable loading onto the expected factor. The difference from the previous extraction was that the sixth and seventh factors in Table 21 were combined and were loaded on by WC1 to WC5. Only one variable loaded onto its factor with a value of $r < 0.5$ (WC10, $r = 0.436$). WC10 cross-loaded onto two other factors (r = 0.370 and r = 0.318) instead of one factor on the previous extraction. WC15 again cross-loaded onto two other factors (r = 0.337 and r = 0.375); WC18 continued to cross-load onto one factor (r = 0.356). WC4 now cross-loaded onto one factor (r = 0.324). WC24 ceased to cross-load onto other factors. None of the cross-loadings had values of r > 0.375 (14.1% of variance).

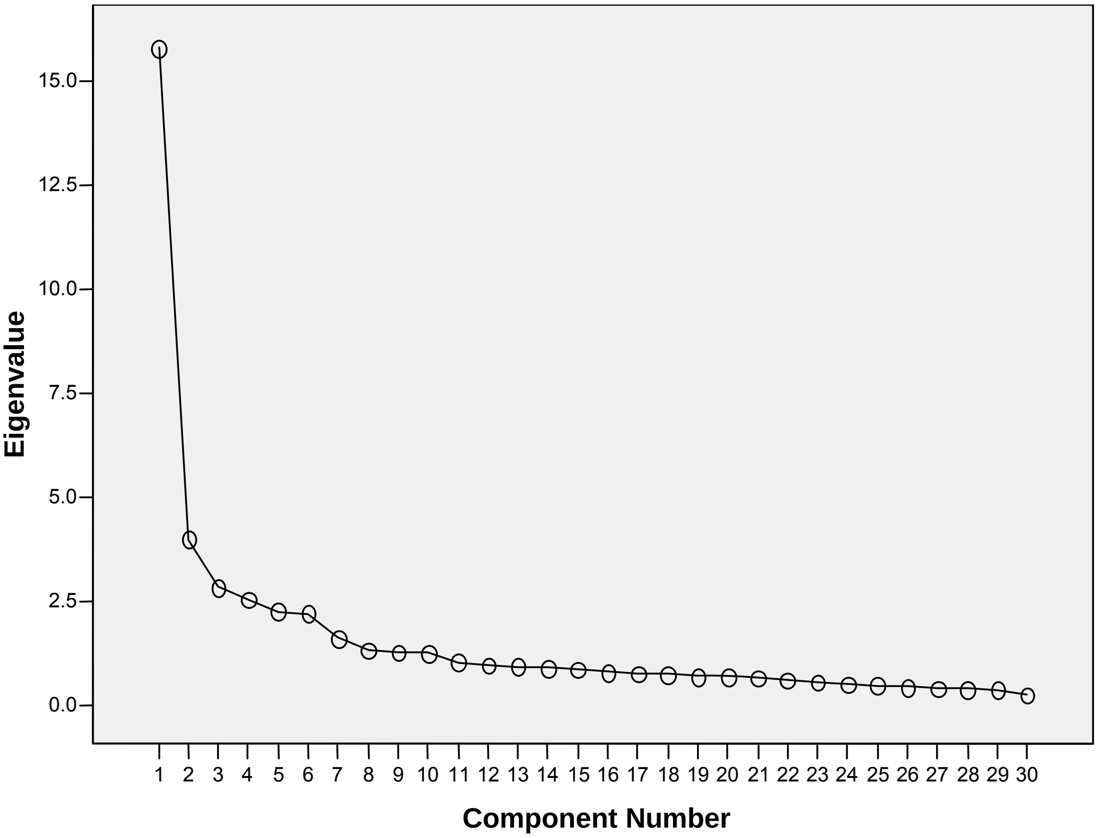


Figure 2 Scree plot for extraction of six psychosocial factors

Table 22 Variance explained by a six factor model

Component	*Rotation Sums of Squared Loadings*		
	Total	*% variance*	*Cumulative % variance*
1	3.414	11.38	11.38
2	3.205	10.68	22.06
3	3.093	10.31	32.37
4	3.070	10.23	42.60
5	2.978	9.93	52.53
6	2.483	8.28	60.81

Extraction Method: Principal Component Analysis.

Table 23 Rotated component matrix for six factor model after rescaling

	1	*2*	*3*	*4*	*5*	*6*
WC1						.619
WC2						.718
WC3						.719
WC4				.324		.643
WC5						.573
WC6			.614			
WC7			.776			
WC8			.787			
WC9			.742			
WC10	.370	.318	.436			
WC11				.771		
WC12				.779		
WC13				.720		
WC14				.645		
WC15		.337		.527	.375	
WC16					.751	
WC17					.748	
WC18		.356			.617	
WC19					.572	
WC20					.667	
WC21		.714				
WC22		.671				
WC23		.688				
WC24		.653				
WC25		.708				
WC26	.825					
WC27	.566					
WC28	.778					
WC29	.668					
WC30	.713					

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

6.1.3 Conclusion on factor structure

It was concluded that the desired structure of six factors in the psychosocial questionnaire had been achieved with only small errors. It was therefore decided that the structure was adequately robust for the factors to be used as covariates in analysis of the longitudinal data from the study.

It was also concluded that there was scope for minor amendment of the question set to improve the factor structure. Re-analysis of the data after the addition of data collected from a group of approximately 150 HGV instructors confirmed this conclusion. The amendments were made before the questionnaire was used in later studies (Marlow *et al.,* 2005) and are not described here.

The names assigned to the six factors are given in Table 24.

Table 24 Names of the psychosocial factors

Factor	*Factor name*	*Items*	*Component*	*% variance*
WCF1	Influence on and control over work	WC1 – WC5	6	8.28%
WCF2	Supervisor climate	WC6 – WC10	3	10.31%
WCF3	Stimulus from the work itself	WC11 – WC15	4	10.23%
WCF4	Relations with fellow workers	WC16 – WC20	5	9.93%
WCF5	Psychological work load	WC21 – WC25	2	10.68%
WCF6	Management commitment to health and safety	WC26 – WC30	1	11.38%

6.2 RELIABILITY OF THE PSYCHOSOCIAL SCALES

Reliability analysis of the six scales was carried out using SPSS v14.0. Missing values were excluded within the analysis of each factor. The results are summarised in Table 25:

Table 25 Reliability analysis of the psychosocial question set

Factor	*No of items*	*No of cases*	*Cronbach's α*	*Mean*	*SD*	*Range of α if one item deleted*
WCF1	5	507	0.749	14.77	4.805	0.675 – 0.749
WCF2	5	507	0.832	16.23	4.939	0.758 – 0.832
WCF3	5	510	0.846	15.11	5.176	0.802 – 0.826
WCF4	5	510	0.812	18.74	4.266	0.755 – 0.798
WCF5	5	510	0.810	16.02	4.799	0.750 – 0.810
WCF6	5	511	0.851	17.26	4.991	0.790 – 0.851

All of the values of Cronbach's Alpha exceeded 0.7 and five of the six exceeded 0.8. There were no major changes on any scale if single items were deleted. WCF1 was the factor with the lowest reliability, which had also been found at the piloting stage.

These results therefore confirmed the analysis carried out when the questionnaire was piloted and reinforce the conclusion that the scales are reliable.

6.3 REPORTS OF MUSCULOSKELETAL TROUBLE ON THE NMQ

Prevalences for the baseline data obtained with the NMQ have been reported by Pinder (2004) and were later compared with data obtained from other populations using the same questionnaire (Marlow *et al.,* 2005; Lee and Jones, 2004).

Table 26 reports the proportions of subjects reporting musculoskeletal trouble in the nine body areas of the NMQ section of the questionnaire. It also gives disability rates for the previous three months for the nine body parts and, finally, whether the respondent considered that any trouble experienced in the previous three months had been caused or made worse by the job.

The most common site for reporting trouble in the previous three months was the low back at 44%, followed by the wrists/hands at 32%. Prevalence rates in the neck, shoulders, knees and ankles/feet were in the range of 22% – 30%. The upper back, hips/thighs/buttocks and elbows were in the region of 12% – 15%. Seven-day prevalences, while naturally lower, showed the same patterns, with the most common site again being the low back at 22%. The greatest level of disability in was caused by trouble in the low back, at 13% of subjects. The greatest rate of reporting problems as work-related was in the low back, where 24% of respondents indicated that their low back trouble was either caused or made worse by work.

Table 26 Reports of musculoskeletal trouble in nine body areas (N = 515)

	Trouble in the previous 3 months	***Trouble in the previous 7 days***	***Disability due to trouble in the previous 3 months***	***Trouble in the previous 3 months caused by the job***	***Trouble in the previous 3 months made worse by the job***
Neck	29.6%	15.8%	6.7%	8.9%	4.9%
Shoulders	28.5%	15.3%	6.2%	9.6%	4.2%
Elbows	15.1%	7.4%	3.8%	6.9%	1.6%
Wrists/ hands	31.7%	19.2%	5.8%	11.8%	5.2%
Upper back	12.4%	5.4%	5.0%	4.2%	2.6%
Low back	43.6%	21.8%	12.8%	15.5%	8.0%
Hips/thighs/buttocks	13.6%	7.5%	4.0%	3.0%	3.2%
Knees	23.5%	14.2%	6.8%	4.2%	6.4%
Ankles/ feet	22.2%	16.4%	5.4%	6.9%	6.5%

Table 27 shows rates of reports of trouble in the previous seven days, of disability in the previous three months and of reports of the work-relatedness of the trouble relative to reports of trouble in the previous three months. Weekly prevalences of trouble varied across body parts between 44% and 73% of three-monthly trouble, with the mean across body parts being 55%. These figures reflect the episodic nature and short duration of much musculoskeletal trouble leads. In other words, and for example, though 44% of the total sample reported having had trouble in the low back in the previous three months, this problem did not recur in the previous week for 51% of the 223 individuals. Therefore, they had experienced low back trouble in the relatively recent past but had recovered.

Table 27 Reports of seven day trouble, disability and work-relatedness relative to reports of trouble in the previous three months

	Trouble in the previous 3 months (N)	***Trouble in the previous 7 days***	***Disability***	***Trouble caused by work***	***Trouble made worse by work***	***Caused: Made worse ratio***
Neck	150	53.3%	22.7%	30.0%	16.7%	1.80
Shoulders	143	53.8%	21.7%	33.6%	14.7%	2.29
Elbows	76	48.7%	25.0%	46.1%	10.5%	4.39
Wrists/ hands	159	60.4%	18.2%	37.1%	16.4%	2.26
Upper back	62	43.5%	40.3%	33.9%	21.0%	1.61
Low back	223	49.3%	29.1%	35.4%	18.4%	1.92
Hips/thighs/buttocks	69	55.1%	29.0%	21.7%	23.2%	0.94
Knees	118	60.2%	28.8%	17.8%	27.1%	0.66
Ankles/ feet	112	73.2%	24.1%	31.3%	29.5%	1.06

Disability varied across body parts between 18% and 40% of three-monthly trouble, with a mean of 27%. Of the cases of low back trouble in the previous three months, only 29% had caused disability, implying that 71% of cases were insufficiently severe to affect the respondents' normal activities, let alone cause time off work.

The data on work-relatedness of the trouble shows considerable variation between body parts, particularly in the Caused: Made worse ratio. As different body parts are exposed to different stresses and risk factors for the development of MSDs, pre-existing conditions or problems such as arthritis may be exacerbated by work at different rates in different parts of the body. The Caused: Made worse ratio varied between 0.66 in the knees and 4.39 in the elbows.

Table 28 compares the prevalences of trouble for the three month and seven day periods with the figures for a group of care home workers and a group of podiatrists surveyed by HSL using the same questionnaire (Marlow *et al.,* 2005; Lee and Jones, 2004). When comparing the three groups it is worth noting that the subjects in this study were a deliberately heterogeneous group of industrial workers who, while all involved in regular manual handling as part of their jobs, experienced a wide range of demands, from very light to very heavy. By contrast, the podiatrists were a homogenous group drawn from a single profession. The group of care workers was quite homogenous with 75% being care assistants and 15% managers and/or qualified nurses.

Table 28 Comparison of reports of musculoskeletal trouble with results of HSL surveys of other occupational groups

	This study (N = 500 - 511)		***Care homes (N = 818 - 828)***		***Podiatrists (N = 148 - 149)***	
	3 months trouble	***7 days trouble***	***3 months trouble***	***7 days trouble***	***3 months trouble***	***7 days trouble***
Neck	29.6%	15.8%	16.0%	7.4%	54.4%	30.4%
Shoulders	28.5%	15.3%	16.2%	7.9%	47.7%	31.1%
Elbows	15.1%	7.4%	4.2%	2.0%	10.7%	8.1%
Wrists/ hands	31.7%	19.2%	12.8%	6.2%	47.7%	25.7%
Upper back	12.4%	5.4%	10.3%	5.7%	30.2%	16.2%
Low back	43.6%	21.8%	27.8%	13.2%	71.1%	44.6%
Hips/thighs/buttocks	13.6%	7.5%	8.2%	4.0%	18.8%	14.1%
Knees	23.5%	14.2%	12.0%	5.6%	32.2%	13.4%
Ankles/ feet	22.2%	16.4%	10.4%	5.1%	11.4%	6.1%

6.4 WORKFORCE ATTITUDES TO WORK CHARACTERISTICS

Table 29 gives the means and 95% CIs of the factor scores for the six psychosocial factors of the Work Characteristics section of the questionnaire. Because of the way in which the questions were phrased and the factor scores calculated, higher scores show stronger agreement with the questions and more positive attitudes to each factor. The most negative possible score is 5 and the most positive possible score is 25. Therefore, a score of 15 indicates neutrality of opinion. It is therefore clear that overall, attitudes measured on factors WCF1 and WCF3 were neutral, but were significantly positive on the other four factors.

Table 29 also compares the scores on the Work Characteristics scales obtained in this study and in the studies of care homes staff and podiatrists. It demonstrates that the responses on all of the scales from the care staff are significantly ($P < 0.05$) more positive than the responses from this study and from the podiatrists. The scores for this study and the podiatrists were only significantly different ($P < 0.05$) on WCF2, WCF3, and WCF5.

Table 29 Comparison of Work Characteristics factor scores from HSL studies

	Factor name	*This study* *Mean (95% CI)*	*Care home* *Mean (95% CI)*	*Podiatrist* *Mean (95% CI)*
WCF1	Influence on and control over work	14.69 (14.26 - 15.11)	18.15 (17.81 - 18.50)	15.65 (15.03 - 16.28)
WCF2	Supervisor climate	16.21 (15.77 - 16.65)	21.22 (20.89 - 21.55)	17.53 (16.76 - 18.30)
WCF3	Stimulus from the work itself	14.98 (14.53 - 15.44)	21.23 (20.91 - 21.55)	18.37 (17.66 - 19.08)
WCF4	Relations with fellow workers	18.69 (18.31 - 19.07)	21.77 (21.48 - 22.06)	18.08 (17.38 - 18.77)
WCF5	Psychological work load	15.98 (15.56 - 16.40)	18.20 (17.82 - 18.58)	14.88 (14.24 - 15.52)
WCF6	Management commitment to health and safety	17.17 (16.72 - 17.61)	21.09 (20.74 - 21.44)	17.63 (17.02 - 18.24)

Table 30 compares these baseline results with the results from a series of Swedish studies using the first five factors. The groups studied were:

- Car assembly workers (N = 212) (Rubenowitz, 1989)
- Industrial blue-collar workers (N = 2394) reference data (Johansson *et al.,* 1993)
- White- (N = 209) and blue-collar (N = 241) workers (Johansson and Rubenowitz, 1994)
- Off-license workers (Ingelgård *et al.,* 1996).

These studies did not report SDs for the factor scores so it was not possible to calculate CIs for them. There is considerable variation between the Swedish groups. This variability presumably reflects real differences in the different workforces and in the psychosocial situations that they exist in and suggests that the scales are measuring these differences.

Overall there appears to be a tendency for WCF4, "Relations with fellow workers" to be the most highly scored factor and for WCF1 "Influence on and control over work" and WCF5 "Psychological work load" to be the most poorly scored factors. This can be interpreted as showing that although people feel relatively powerless and stressed at work, they do generally get on well with their fellow workers.

Table 30 Comparison of Work Characteristics mean factor scores with previous Swedish studies.

Factor	*This study*	*45 off-license workers*	*209 white collar workers*	*241 blue collar workers*	*212 car assembly plant workers*	*2394 industrial workers*
WCF1	14.69	17.95	19.32	17.16	16.8	16.3
WCF2	16.21	18.55	18.24	17.3	16	16.7
WCF3	14.98	17.75	19.59	14.73	18.23	17.83
WCF4	18.69	20.3	21.08	19.86	18.87	19.63
WCF5	15.98	17.15	16.22	15.81	14.63	16

7 STATISTICAL METHODS FOR ANALYSIS OF RISK OF LBP

7.1 LOST TIME DUE TO LBP – PERSONAL VARIABLES

7.1.1 Logistic regression

Logistic regression was performed to look at the probability of experiencing LBP during the study period across various possible risk factors. The dependent variable in the analysis was a binary variable indicating whether or not the participant had lost time (light duties or absence) due to LBP during the study period. For participants that dropped out of the study without reporting an episode of lost time due to LBP, it is impossible to tell if they would have experienced LBP if they had continued in the study. For this reason, these 140 participants were excluded from this analysis, leaving 375 participants (Table 31).

Table 31 Reporting of lost time by dropout status

	Dropout	*Non dropout*	*Total*
Lost time due to LBP	11	42	53
No lost time reported	*140*#	322	462
Total	151	364	515

#Excluded from logistic regression analysis

Crude (unadjusted) Odds Ratios (ORs) were estimated for personal variables, lifestyle factors, psychosocial variables and responses to the NMQ. ORs were also estimated with adjustment for age at entry, gender and LBP experience before the study. All variables were entered as a series of indicator variables. The observed relationships were tested for trend by including the covariates as continuous rather than categorical variables where appropriate. Two-way interactions between variables and LBP experience were also assessed. Those variables and interactions that were statistically significant were included in the full logistic regression model.

Three questions on the baseline questionnaire (Appendix 1) related to LBP experience:

- "Have you suffered from low back pain **during the last 12 months**?" (Q12);
- "Have you at any time during the last **three months** had **trouble** (such as **ache, pain, discomfort, numbness, tingling, or pins and needles**) in your lower back (small of back)?" (MSD Q21);
- "Have you had this trouble during the last **seven days**?" (MSD Q22).

The effects of the three variables as covariates were compared using the Akaike Information Criterion (AIC) (Mickey *et al.*, 2004). The criterion is such that the lower the value of the AIC, the better fitting the model. Furthermore, a difference greater than two indicates a marked preference for the model with the smaller AIC.

7.1.2 Survival analysis methods

Cox regression is in many ways similar to logistic regression, but is considered the "better choice" (Callas *et al.,* 1998) for analysis of longitudinal data. It takes into account the length of follow-up and so it was not necessary to exclude participants from the analysis. It also allows for multiple events for each participant and so the numbers of cases/events are greater than logistic regression.

Figure 3 illustrates how the data are setup for survival-time analysis. In this particular example, the participant experienced a failure (absence due to LBP) after 140 days in the study that lasted for 40 days. During this 40-day period, it was not possible for the participant to report a further failure and so was not considered at risk during this period. Once the period of absence finished, the participant was once again at risk of failure events until day 400 when they dropped out.

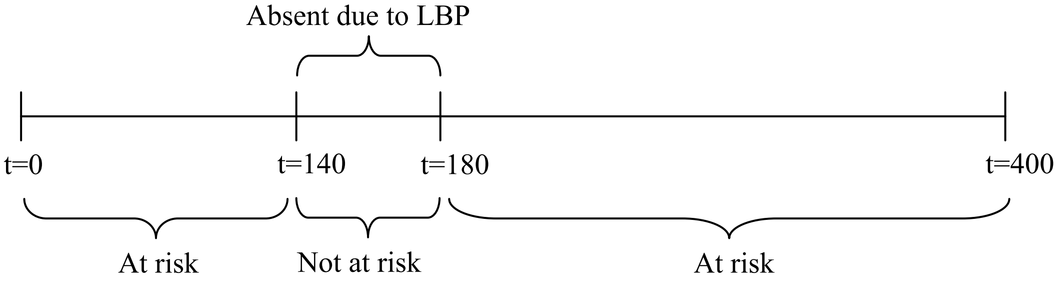


Figure 3 Example set-up for survival analysis

To allow comparisons, the methods used for the survival analysis were equivalent to the ones used in the logistic analysis. The dependent variable was again the binary variable indicating whether or not the participant had lost time (light duties or absence) during the study period. The log-rank test was used to compare survival across groups. Robust variance estimation was used to account for possible clustering due to multiple events/records per participant.

Hazard Ratios (HRs) were estimated for personal variables, lifestyle factors, psychosocial variables and responses to the NMQ. HRs were also estimated after adjustment for age at entry, gender and LBP experience before the study. All variables were entered as a series of indicator variables. The observed relationships were tested for trend by including the covariates as continuous rather than categorical variables where appropriate. Two-way interactions between variables and LBP experience were also assessed. Those variables and interactions that were statistically significant were included in the full Cox regression model. The same three LBP experience questions on the baseline questionnaire (Q12, MSD Q21 and MSD Q22) were used.

7.1.3 Duration of lost time: Accelerated failure-time modelling

The numbers of days that subjects reported as lost from work time due to LBP were modelled as survival-time data (time to return to full work duties) using parametric survival analysis. Accelerated failure-time (AFT) models (also known as accelerated time models, accelerated life models or ln(time) models) focus on time to failure (more specifically the logarithm of time) and what happens to that time for different values of the covariates (Collet, 1994). The exponentiated coefficients of an AFT model are interpreted as time ratios (TRs) for a one-unit change in the corresponding covariate. Therefore, TRs < 1 are associated with a decrease in (return) time and TRs > 1 are associated with a prolonged (return) time. For example, a TR of 2.0 would represent a doubling of lost time duration. There are various possible parametric survival models and the model with the smallest AIC value was chosen from the models fitted on the lost time data with covariates of age, gender and LBP experience. It should be noted that the log–normal model is analogous to linear regression with the logarithm of time as the outcome measure.

For AFT models, the data are setup in a different manner to Cox regression. The analysis time begins when the participant starts a period of absence or light duties due to LBP, and ends when either the participant returns to full duties (event of interest) or the study period ends (right censored observations) (Figure 4). Robust variance estimation was used to account for possible clustering due to multiple events (lost time) per participant.

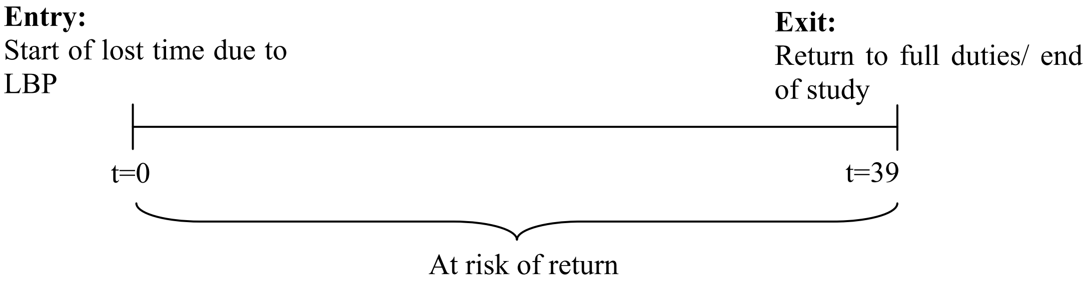


Figure 4 Set-up for AFT models

TRs were estimated for personal variables, lifestyle factors, psychosocial variables and responses to the NMQ. TRs were also estimated with adjustment for age at start of lost time, gender and LBP experience before the study. All variables were entered as a series of indicator variables. The observed relationships were tested for trend by including the covariates as continuous rather than categorical variables where appropriate. Two-way interactions between variables were also assessed. Those variables and interactions that were statistically significant were included in the full AFT model. The overall fit of the final AFT model was assessed using the Cox-Snell residuals. If the model fits the data, these residuals should have a standard exponential distribution with HR = 1. The fit of the model can therefore be verified by estimating the empirical cumulative hazard function with the Cox-Snell residuals as the time variable. If the model fits the data, the plot of the cumulative hazard versus the Cox-Snell residuals should be a straight line with slope 1. Again, the same LBP experience questions on the baseline questionnaire (Q12, MSD Q21 and MSD Q22) were used.

7.2 LOST TIME DUE TO LBP – CLI, MAXIMUM STLI AND TASK VARIABLES

The CLI, maximum STLI and the task variables from the task in each job with the maximum STLI were investigated to see if they were associated with lost time due to LBP or reporting of LBP.

Logistic regression and Cox regression were used to test the CLI and STLI as predictors of lost work time (light duties or absence) due to LBP, and GEEs were used to look at possible associations with reports of LBP. The data were set up as for the personal variables. Due to some subjects changing jobs, both the CLI and the STLI for each participant could change during the study period so this was dealt with by having multiple records for these participants. For logistic regression, robust variance estimation was used to account for possible clustering due to this. For Cox regression, the person-years (time at risk) were divided to reflect the length of time for each exposure – for example, the participant in Figure 5 spent 180 days of the study with a CLI of 1.04 and 220 days with a CLI of 2.06.

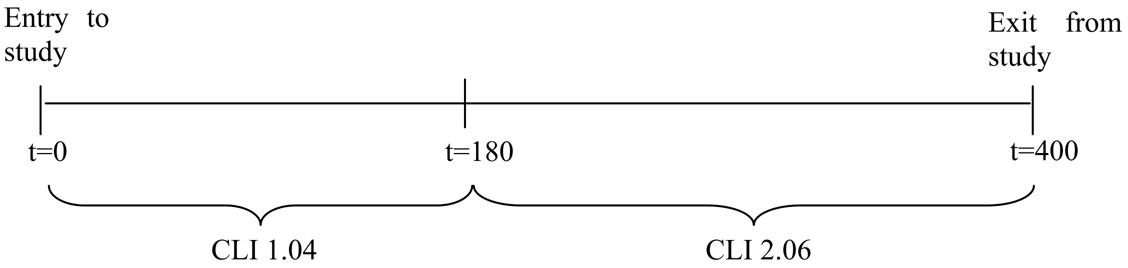


Figure 5 Example of participant with multiple values of CLI during the study period

Changes in job (and hence CLI/STLI) would occur between follow-up questionnaires. Therefore the GEE analysis, which does not use the specific date of LBP but only if it occurred during the follow-up period, would not be able to take this into account. Participants that had multiple values of CLI/STLI were therefore excluded from the analysis (n = 20).

Cut-off points of one and three were used as values of *a priori* interest because they relate to the 1981 AL and MPL (NIOSH, 1981) and the 1991 RWL (Waters *et al.,* 1994). The variables were also entered as continuous covariates to test for trend. It is important to note is that ORs or HRs become unreliable when the numbers of events in a group are small (around ≤ 5), and so results should be treated with caution when this is the case. The ORs / HRs were adjusted for the basic personal variables of age, gender, LBP experience before the study, and weight. Also presented are ORs / HRs adjusted for the models developed for the personal variables.

The task variables involved in calculating the maximum STLI were also investigated for associations with lost time due to LBP (logistic and Cox regression) and reporting of LBP (GEEs). If possible, variables were categorised so that the number of events in each group were no fewer than five. The variables were also entered as continuous covariates to test for trend. Two-way interactions between the task variables and basic personal variables (age, gender, LBP experience and weight) were also assessed.

7.3 ANY REPORT OF LBP

7.3.1 Logistic regression

Logistic regression was performed to look at the probability of reporting LBP during the study period across various possible risk factors. The dependent variable in the analysis was the binary variable indicating whether or not a participant had reported LBP during the study period. For participants that dropped out of the study without reporting LBP, it is impossible to know if they would have experienced LBP if they had continued in the study. For this reason, these participants were excluded from the analysis and 408 participants remained (Table 32).

Table 32 Reporting of any LBP by dropout status

	Dropout	*Non dropout*	*Total*
Reported LBP	44	161	205
No LBP reported	*107*[#]	203	310
Total	151	364	515

 # Excluded from logistic regression analysis

Crude (unadjusted) ORs were estimated for personal variables, lifestyle factors, psychosocial variables and responses to the NMQ. ORs were also estimated with adjustment for age at entry, gender and LBP experience before the study. All variables were entered as a series of indicator variables. The observed relationships were tested for trend by including the covariates as continuous rather than categorical variables where appropriate. Two-way interactions between variables were also assessed. Those variables and interactions that were statistically significant were considered for the full logistic regression model. Both forward and backward selection procedures were performed. The three LBP experience questions on the baseline questionnaire (Q12, MSD Q21 and MSD Q22) were used again.

7.3.2 GEEs

GEEs take into account dependence between repeated measurements on the same subject over time. The response variable of reporting LBP was collected at baseline and, at most, at each of six follow-ups. The reasoning behind using GEEs for this data would be that a participant who reported LBP at one follow-up may be more likely to report it at a follow-up in the future; we have a correlated binary outcome. GEE models describe the average occurrence of the outcome for the group as a whole, and so the data do not need to be balanced. However, GEEs require that the responses are missing completely at random (MCAR) and so participants that did not complete all the follow-ups due to dropout were excluded (N = 135).

To allow comparison with the results of the logistic analysis, equivalent methods were used for the GEE analysis. The dependent variables were the binary variables representing reporting or not reporting LBP at each follow-up. Possible correlation structures were compared using the Quasi-likelihood under the Independence model Criterion (QIC) (Pan, 2001). The QIC is an extension of the AIC, used instead because the GEE method is a non-likelihood based technique, whereas the AIC is based on maximum likelihood estimation. Semi-robust standard errors were used (Huber-White sandwich estimator of variance), which produce valid standard errors even if the working correlation matrix is incorrectly specified.

Crude (unadjusted) ORs were estimated for personal variables, lifestyle factors, psychosocial variables and responses to the NMQ. ORs were also estimated with adjustment for age at entry, gender and LBP experience before the study. All variables were entered as a series of indicator variables. The observed relationships were tested for trend by including the covariates as continuous rather than categorical variables where appropriate. Two-way interactions between variables were also assessed. Those variables and interactions that were statistically significant were considered for the full GEE model. Both forward and backward selection procedures were performed. The fit of the final model was assessed using an extension of the Hosmer-Lemeshow goodness of fit test (Hardin and Hilbe, 2003). The three LBP experience questions on the baseline questionnaire (Q12, MSD Q21 and MSD Q22) were used again. The QIC_u was used as an approximation to the QIC (Pan, 2001) to determine the best subset of covariates for each GEE model. Again, the model with the smallest QIC_u criterion is preferred. However, there is not yet a proposed method to discriminate the difference between two candidate models having very similar QIC_u values.

8 SUMMARY OF RESULTS OF ANALYSIS OF THE RISK OF LBP

8.1 LOST TIME DUE TO LBP – ASSOCIATIONS WITH PERSONAL VARIABLES

Logistic regression and Cox regression were performed to investigate whether there were associations between the personal variables reported on the baseline questionnaire (gender, anthropometry, hours of work, history of LBP, exercise, NMQ responses and psychosocial scale scores, etc.) and the risk of losing work time (light duties or absence) due to LBP. Results from the two techniques were similar.

- Experiencing LBP in the 12 months before the study increased the risk of losing work time due to LBP during the study.
- There was a significant interaction between BMI and pre-study LBP experience.
- There was also a statistically significant decrease in risk of lost time with increasing supervisor climate score (psychosocial variable).
- Using the Akaike Information Criterion (AIC), it was shown that experience of LBP during the previous 12 months as a three-category variable (categories of: No LBP; LBP, but work not affected; LBP with lost time from work) fitted the data better than using LBP during the previous 12 months, three months or seven days (No; Yes categories).

The final logistic model to predict incidence of work loss due to LBP included age, gender, supervisor climate and the interaction between BMI and pre-study LBP experience. The final Cox regression model also included regular exercise (No; Yes: HR = 0.47, 95% CI 0.28 – 0.79).

8.2 DAYS OF LOST TIME DUE TO LBP – ASSOCIATIONS WITH PERSONAL VARIABLES

AFT modelling was performed to investigate whether there were associations between the personal variables and the duration of lost work time (light duties or absence) due to LBP. There were 53 participants who experienced 66 periods of lost work time, totalling 1,691 days.

- Those who had experienced LBP that did not affect their work in the 12 months before the study had an increased duration of lost time due to LBP.
- Those who had greater BMIs were predicted to have longer periods of lost time due to LBP.
- None of the responses from the NMQ, including those associated with LBP, were significantly associated with duration of lost time.
- There were significant interactions found between age and weekly working hours, age and smoking status (including the number of cigarettes smoked), and age and the psychosocial variables (excluding influence and control over work).

The final AFT model to predict duration of lost work time due to LBP included gender, LBP experience, BMI, the interaction between age and relations with fellow workers, and the interaction between age and smoking status.

8.3 LOST TIME DUE TO LBP – CLI, MAXIMUM STLI AND TASK VARIABLES

Logistic regression and Cox regression were used to examine relationships between the risk of losing work time (light duties or absence) due to LBP, and the CLI, maximum STLI and task variables that contributed to the maximum value of the STLI. GEEs were also used to examine associations between these variables and reports of LBP, with or without lost time.

- There were no statistically significant results found for the CLI.
- The GEE analysis found a statistically significant reduction in risk associated with increasing STLI, but this was no longer statistically significant once basic personal variables were adjusted for.
- There were no statistically significant task variables found using logistic regression. However, the effect of the vertical offset of the hands from 750 mm was found to depend on age (P = 0.04).
- In the Cox regression, there was a statistically significant increase in the risk of lost time with increasing maximum horizontal hand distance (P = 0.01).
- There was a statistically significant increase in risk with increasing vertical offset of the hands from 750 mm, but this was no longer significant after adjustment for basic personal variables.
- It was found that the effect of the horizontal location of the hands, the vertical offset from 750 mm and the lifting frequency depended on the age of the participant (P = 0.04, P = 0.01 and P < 0.01 respectively).
- During the GEE analysis, it was found that fair/good hand/object coupling was associated with increased odds of reporting LBP as compared to poor coupling (OR = 2.5, 95% CI 1.3 – 4.9).
- The effect of load weight and horizontal location of the hands was found to depend on the age of the participant (P = 0.01 and P = 0.03 respectively). The effect of the vertical location of the hands depended on the weight of the participant (P = 0.02).

8.4 ANY REPORT OF LBP– PERSONAL VARIABLES

Logistic regression and GEEs were used to investigate possible risk factors associated with reports of any LBP in the three months prior to each follow-up. Results from the two techniques were similar, but the GEEs detected more statistically significant interactions.

- Experiencing LBP in the 12 months before the study increased the odds of reporting LBP during the study.
- There was a statistically significant decrease in odds of reporting LBP for males who exercised regularly and who regularly did aerobic exercise. This decrease was not seen for females.
- Using GEEs, there was a statistically significant increase in odds for females who worked more than 40 hours a week as compared to females who worked less than 40 hours a week. This increase was not seen among males.
- Also using GEEs, there was a significant interaction between gender and age, with females at greater ages having lower odds of reporting LBP than females at younger ages. There was a non-significant increase in odds with age for males.
- There was a statistically significant decrease in odds of reporting LBP with increasing psychological workload (psychosocial variable).

- There was a statistically significant interaction between management commitment to health and safety (psychosocial variable) and pre-study LBP experience, but the exact nature of the interaction differed depending on whether logistic regression or GEEs were used.
- Using GEEs, there was also a significant interaction between influence and control over work (psychosocial variable) and pre-study LBP experience. Those with greater influence and control over their job but no experience of LBP in the 12 months before the study had increased odds of reporting LBP. However, there was no increase in risk with increasing control in individuals who had experienced LBP before the study.
- The final GEE model differed substantially from the final logistic model because of the increased number of statistically significant interactions found when using GEEs.

8.5 INJURIES OTHER THAN LBP – PERSONAL VARIABLES

Logistic regression and Cox regression were performed to investigate associations between the personal variables and the risk of losing work time (light duties or absence) due to injury other than LBP. Results from the two techniques were similar and differed to those obtained from the investigation into lost work time due to LBP.

- Experiencing LBP 12 months before the study increased the risk of losing work time due to injury during the study, and a more positive supervisor climate score was associated with a decrease in risk of lost time due to injury. Both of these associations were also found for lost time due to LBP.
- There were statistically significant associations with age, length of employment, daily travel time to and from work in a vehicle, and psychological workload, which were not present for lost work time due to LBP.
- Whereas the NMQ questions on the lower back were associated with lost time due to LBP, it was the NMQ questions to do with trouble with the neck and shoulders, and elbows and wrists/ hands that were associated with lost time due to other injury.

AFT modelling was performed to investigate possible associations between various factors and duration of lost work time (light duties or absence) due to injury other than LBP. Results differed to those obtained from duration of lost time due to LBP.

- Experiencing LBP before the study was not significantly associated with duration of lost time due to injury.
- Exercising regularly, no matter if this was aerobic or not, was associated with increased duration of lost time due to injury, which was not present for duration of lost time due to LBP.

9 DETAILED RESULTS OF ANALYSIS OF RISK OF LBP

9.1 STANDARD SYMBOLS

*	significant at $P \leq 0.05$
**	significant at $P \leq 0.01$

9.2 DESCRIPTIVE STATISTICS

9.2.1 Industry sectors represented

The 515 subjects recruited at baseline came from nineteen plants belonging to twelve firms that represented the following industry sectors:

- General manufacturing
- Engineering
- Pharmaceuticals
- Parcel distribution
- Warehousing
- Leather processing
- Food processing

9.2.2 Personal data

Descriptive statistics are presented by Question 12 of the baseline questionnaire: “Have you suffered from LBP during the last 12 months?” Table 33 shows the number of participants, dropouts and cases. Group comparisons of continuous variables were performed with analysis of variance or the Kruskal-Wallis test, as appropriate.

Of the 515 workers recruited at baseline nearly 30% dropped out before the end of the study (Table 33). There were statistically significant differences between previous LBP experience groups for length of employment and time spent travelling in a vehicle to and from work (Table 34). There were also statistically significant differences between groups for all psychosocial variables (Table 35). It should be noted that the psychosocial variables have had their baseline shifted by subtracting 15 from each value. This means that the neutral middle value is now zero and scores now range from –10 to 10 with negative scores representing negative attitudes and positive scores represent positive attitudes.

Table 33 Number of participants, dropouts and cases by LBP experience in the 12 months before the study

	No LBP during previous 12 months	*LBP during previous 12 months*		*Total*
		Work not affected	*Lost time*	
Number	301	151	63	515 (100%)
Dropout	92	42	17	151 (29%)
Cases during study				
Any report of LBP	68	93	44	205 (40%)
Lost time due to LBP	17	15	21	53 (10%)
Absence due to LBP	15	10	18	43 (8%)
Lost time due to injury	22	16	17	55 (11%)
Absence due to injury	20	14	15	49 (10%)
Male	244	124	49	417 (81%)

Table 34 Distribution of personal variables for participants at baseline by LBP experience

	No LBP during previous 12 months	*LBP during previous 12 months*		*P-value*[#]	*Total*
		Work not affected	*Lost time*		
Age (years)	38.0 (10.8)	39.2 (10.0)	41.3 (9.9)	0.053	38.7 (10.5)
Weight (kg)	79.7 (14.2)	81.1 (13.6)	79.8 (14.0)	0.590	80.1 (14.0)
Height (m)	1.7 (0.1)	1.7 (0.1)	1.7 (0.1)	0.855	1.7 (0.1)
BMI (kg/m^2)	26.1 (4.1)	26.5 (3.8)	26.3 (3.4)	0.564[†]	26.3 (3.9)
Time with employer (years)	7.4 (8.2)	8.7 (8.4)	10.4 (9.0)	0.001**[†]	8.1 (8.4)
Hours worked per week	40.4 (5.6)	41.1 (6.7)	40.9 (6.1)	0.412[†]	40.7 (6.0)
Travel time per day (min.)	30.8 (28.4)	30.1 (31.5)	38.5 (21.6)	0.001**[†]	31.5 (28.7)

Data are means with SDs in parentheses

#P-value for analysis of variance, unless otherwise specified

† Kruskal-Wallis test

Table 35 Distribution of psychosocial variables for participants at baseline by LBP experience

	No LBP during previous 12 months	*LBP during previous 12 months*		*P-value[#]*	*Total*
		Work not affected	*Lost time*		
Influence on and control over work	0.1 (5.0)	-0.2 (4.3)	-2.7 (4.6)	< 0.001**	-0.3 (4.8)
Supervisor climate	1.8 (4.9)	0.8 (5.1)	-0.5 (4.7)	0.003**	1.2 (5.0)
Stimulus from the work itself	0.9 (5.1)	-0.9 (5.0)	-2.3 (4.9)	< 0.0001**	0.0 (5.2)
Relations with fellow workers	4.4 (4.1)	3.0 (4.3)	2.0 (4.3)	< 0.001**†	3.7 (4.3)
Psychological work load	1.9 (4.7)	-0.4 (4.7)	-0.2 (4.4)	< 0.0001**	1.0 (4.8)
Management commitment to health & safety	3.0 (5.0)	1.1 (4.7)	0.6 (4.8)	< 0.001**†	2.2 (5.0)

Data are means with SDs in parentheses

Positive scores represent a positive attitude on the scale; negative scores represent a negative attitude

#P-value for analysis of variance, unless otherwise specified

† Kruskal-Wallis test

9.3 REASONS FOR DROPPING OUT OF THE STUDY

Of the 515 subjects that entered the study by completing a baseline questionnaire, no LBP or injury follow-up data were obtained for 17. This gives a sample size of 498 subjects for whom longitudinal data were recorded. The reasons that subjects became dropouts from the study are summarised in Table 36.

Of the recruited subjects, 416 were male and 99 (19.2%) were female, of whom four dropped out due to pregnancy. The rate of dropout of female subjects due to pregnancy was therefore 4.0%.

Table 36 Reasons subjects dropped out of the study (N = 515)

Reason	*N*	*%*
Changed to job outside study	104	20.2%
Job redesigned	6	1.2%
Made redundant	3	0.6%
Injured	15	2.9%
Illness	9	1.7%
Other reason, (including pregnancy)	6 (4 pregnancies)	1.2%
Unable to contact / asked to dropout etc	8	1.6%
Total subjects dropped out	151	29.3%
Total subjects changed to another job in the study	31	6.0%
Total dropout / job change	182	35.3%

Table 37 gives the profile, by three month follow-up periods, of when subjects dropped out of the study. Numbers ranged between 17 and 34 per quarter. The total dropout rate was 29.3%, which is equivalent to an annual dropout rate of 19.5%, which is close to the actual dropout rate of 19.0% for the first four quarters of follow-up.

Table 37 Profile of when subjects dropped out of the study

	0 – 3 months	*3 – 6 months*	*6 – 9 months*	*9 – 12 months*	*12 – 15 months*	*15 – 18 months*
Number	34	30	17	17	22	31
Cumulative	34	64	81	98	120	151
Cumulative percent	6.6%	12.4%	15.7%	19.0%	23.3%	29.3%

Examination of the jobs of subjects who had been identified during follow-up as changing to another job in the study showed 14 who had changed job title or location of work but were in fact exposed to the same amount of manual handling. A total of 31 changed to a job with different exposure to manual handling (Table 38). Of the 45 individuals who reported as changing to another job that was identified as being in the study, four reported two moves.

Table 38 Pattern of within-study job changes during the follow-up

	FU1	*FU2*	*FU3*	*FU4*	*FU5*	*FU6*	*Total*
Change in exposure	6	11	4	6	2	2	31
No change in exposure	2	4	5	5	2	0	18
Total	8	15	9	11	4	2	49

A number of participants who changed job at the final follow-up were treated as dropouts from the date of the job change because the time in the study after the change was very short (e.g., four days).

9.4 NUMBER OF SUBJECTS PER JOB

The initial hope had been to include only jobs where there were multiple volunteers to take part in the study. This proved to be impractical, as very many jobs in industry do not have large numbers performing the job in any particular workplace. Moreover, even when there are large numbers within the same department they will tend to perform different jobs. This is not surprising since mechanisation is most easily applied to repetitive jobs with large numbers performing them. Also, there has been a tendency to make jobs more varied, through increased numbers of tasks or through job rotation, along with an increase in skill requirements that leads to small numbers of individuals being responsible for varied aspects of the jobs in a workplace. All of these factors tend to divide workforces into large numbers of small groups of individuals.

In many workplaces, only a minority of employees in eligible jobs elected to take part in the study. This meant, for example, that a job with eight employees could be represented in the study by only two individuals.

Subjects were found to be performing 135 unique jobs. In addition, 26 jobs were identified that involved rotation on at least a daily basis between two or more of the unique jobs, making the total 161 jobs. The distribution at baseline of the 515 subjects is shown in Figure 6. Jobs with zero subjects were only carried out as a part of a rotation.

The distribution of individuals across the jobs where tasks were coded is shown in Figure 7. Initially coding was carried out in the sequence in which subjects entered the study. When it was decided to restrict coding and to carry out analysis of an incomplete set of task data, preference was given to coding jobs with larger numbers of subjects in order to maximise the number of subjects. This resulted in 73 (54%) of 135 unique jobs and 13 (50%) of 26 job rotations being coded, giving 86 (53%) of the 161 jobs. However, 68% (352/515) of the subjects were included at baseline, with another three subjects being included in jobs they moved into during the study.

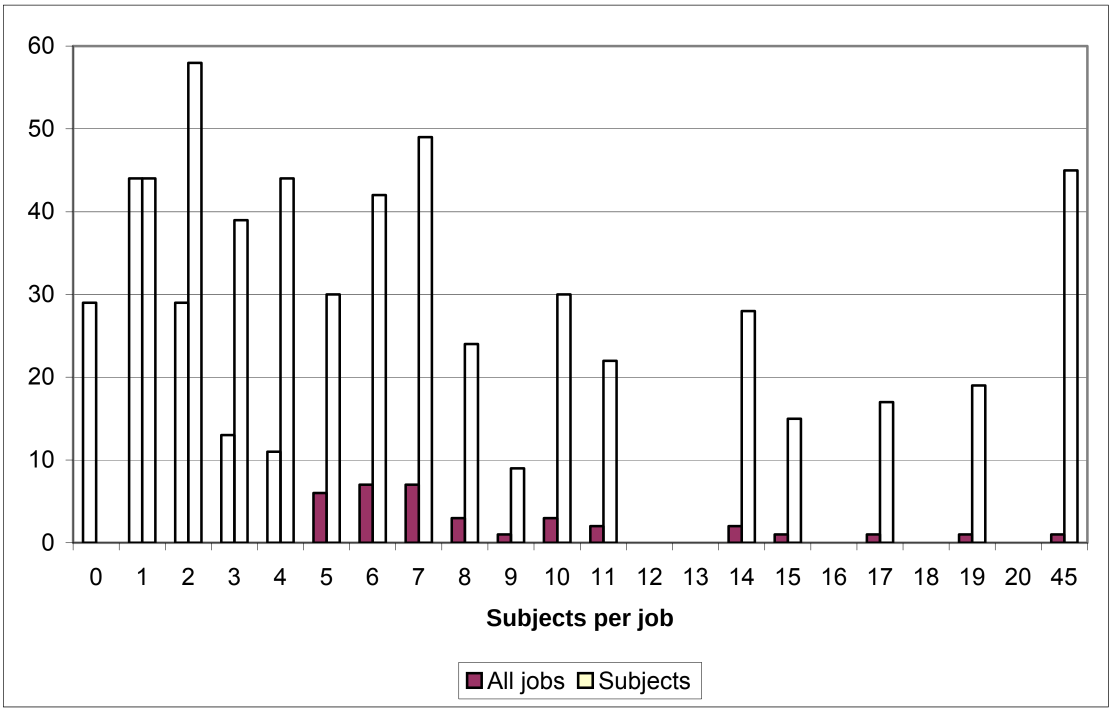


Figure 6 Distribution of numbers of subjects per job

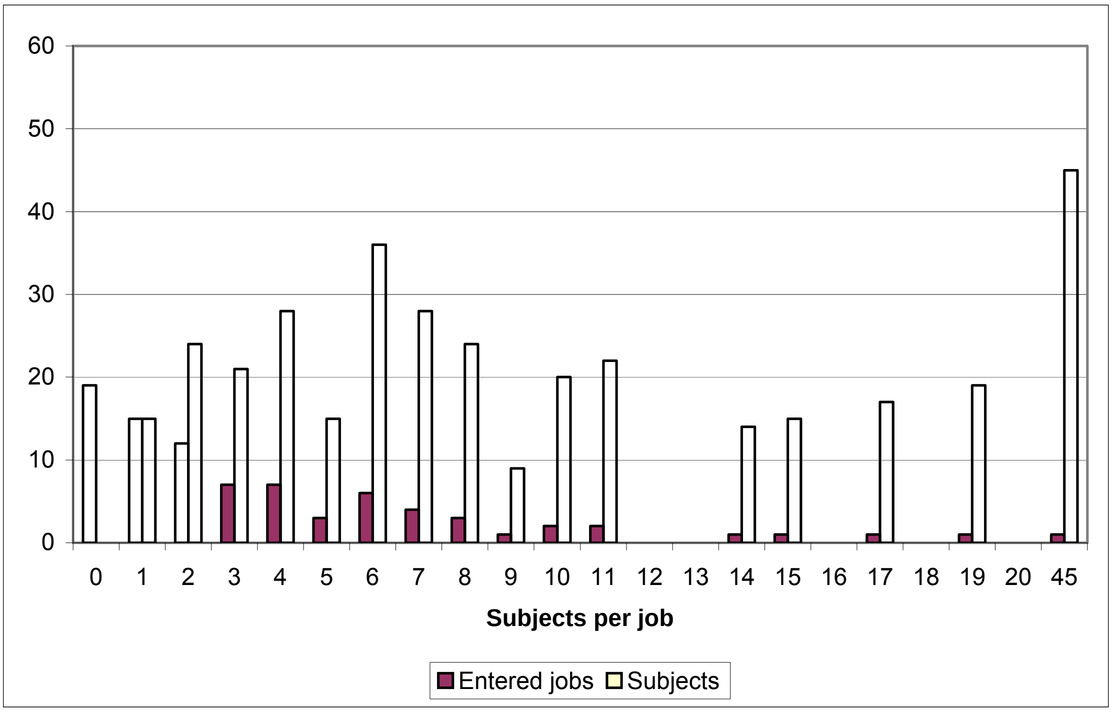


Figure 7 Distribution of numbers of subjects in jobs with coded task data

9.5 MOVEMENT BETWEEN REPORTING AND NOT REPORTING LBP

The episodic and recurrent nature of LBP means that individuals move between reporting and not reporting LBP in the three-month periods before the baseline survey and before each follow-up. The movement of subjects between these states is shown in Figure 8 for the period between the baseline and the first three follow-ups. Only data from subjects with responses at all six follow-ups are included (N = 283). The increasing complexity of the diagram as the number of follow-ups is increased and the number of empty cells that occur both make a diagram showing movement over further follow-ups too complex for easy interpretation.

It is noticeable that the numbers of reports of LBP at the three follow-ups are approximately constant (72, 58 and 68, equal to 25%, 20% and 24%) but much less than the baseline figure (46%). This discrepancy may be related to the different questionnaires used at baseline and at follow-ups and the different ways they were administered.

The diagram illustrates the fact that 16 of 154 subjects who had been free of LBP at baseline reported it at three months, but 12 of these reported being free of LBP in the three to six month period. Of the 129 subjects who reported LBP at baseline, 73 did not report it at three months. Only 127 of the 283 subjects (45%) were free of LBP throughout the first nine months of the study, meaning that 55% reported an experience of LBP in that period. However, only 33 subjects (12%) reported LBP at baseline and all of the first three follow-ups, showing that only a minority of individuals are constant or regular sufferers from LBP.

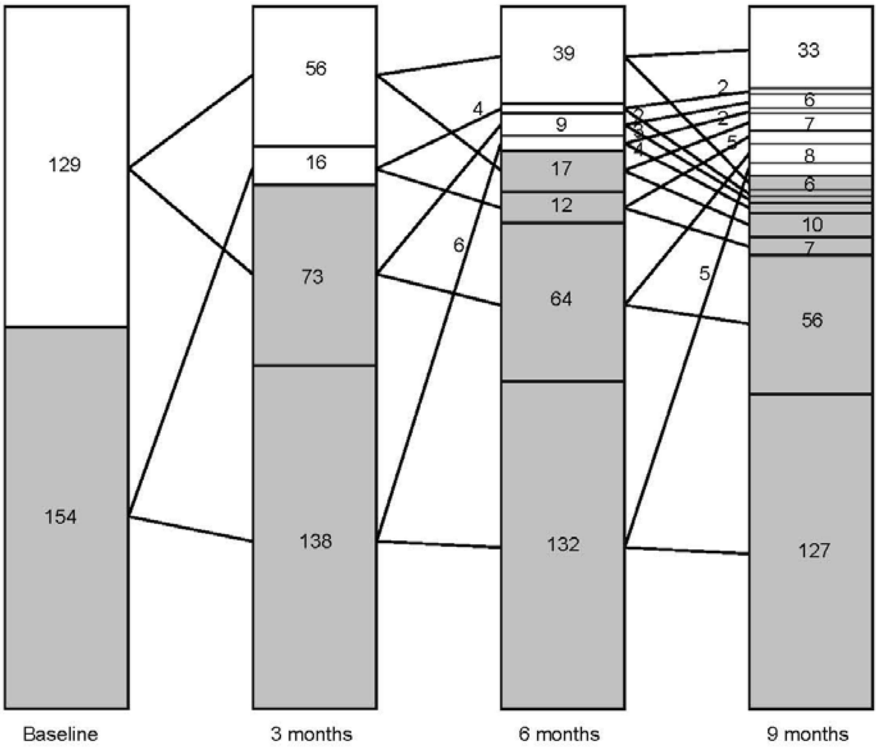


Figure 8 Movement between reporting (unshaded cells) and not reporting (shaded cells) LBP over the first three follow-ups of 283 subjects

9.6 PERSONAL VARIABLES AND LOST TIME (LIGHT DUTIES AND/OR ABSENCE) DUE TO LBP

9.6.1 Logistic regression results

LBP experience was significantly associated with lost time due to LBP during the study period (Table 39). People that had suffered from LBP resulting in lost time before the study had eight times the odds of lost time during the study as people who had not experienced LBP before the study (OR = 8.6, 95% CI 4.1 – 18.3). There was a significant interaction between BMI and LBP experience before the study (P = 0.0007). Those with a higher BMI were at greater odds of lost time if they had not experienced LBP before the study. However, those with a higher BMI were at lower odds of lost time if they had experienced LBP that had not resulted in lost time before the study (Table 40 and Figure 9). There were no significant associations found between lost time and lifestyle factors (Table 41).

Table 42 shows the crude and adjusted ORs associated with the psychosocial variables. Influence and control over work, Supervisor climate, and Management commitment to health and safety all showed significant negative association with the probability of lost time. However, after adjustment for age, gender and LBP experience only the Supervisor climate variable remained significant.

Those who reported experiencing trouble with the upper back or lower body (hips/ thighs/ buttocks, knees and ankles) were at greater odds of lost time (upper back: OR = 2.3, 95% CI 1.1 – 4.9; lower body: OR = 2.3, 95% CI 1.3 – 4.3). However, this increase was no longer significant after adjustment for age, gender and LBP experience (Table 43).

Those who reported experiencing trouble with the lower back during both the previous seven days and the previous three months were at greater odds of lost time (seven days: OR = 2.6, 95% CI 1.4 – 4.8; three months: OR = 4.1, 95% CI 2.1 – 7.9). Among those who reported experiencing trouble with the lower back during the previous three months, increased odds of lost time was observed if the trouble prevented normal activities (Table 44).

The model that included the question regarding lower back trouble during the previous three months had a lower AIC than using lower back trouble during the previous seven days or LBP in the previous 12 months (No; Yes). However, the model that included LBP experience during the previous 12 months as a categorical variable (No; Yes, work not affected; Yes, lost time) had the lowest AIC (Table 45).

The final logistic model (before inclusion of NIOSH parameters) included age, gender, supervisor climate, and the interaction between BMI and LBP experience. The Hosmer-Lemeshow goodness-of-fit statistic indicated that this was a reasonable model (P = 0.6034) (Table 46).

Table 39 Crude and adjusted ORs for lost time due to LBP by personal variables

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR*[#] *(95% CI)*
LBP during previous 12 months				
No	196	17	1.0	
Yes: work not affected	98	15	1.8 (0.8 – 3.7)	
Yes: lost time	28	21	8.6 (4.1 – 18.3)**	
P-value for continuous model			< 0.0001**	
Gender				
Male	263	45	1.0	
Female	59	8	0.8 (0.4 – 1.8)	
Age (years)				
< 30	59	11	1.0	
30 –	117	18	0.8 (0.4 – 1.9)	
40 +	145	24	0.9 (0.4 – 1.9)	
P-value for continuous model			0.925	
Weight (kg)				
< 70	80	14	1.0	1.0
70 –	83	12	0.8 (0.4 – 1.9)	0.7 (0.3 – 1.8)
80 –	79	16	1.2 (0.5 – 2.5)	1.2 (0.5 – 2.9)
90 +	72	10	0.8 (0.3 – 1.9)	0.7 (0.3 – 1.9)
P-value for continuous model			0.705	0.812
Height (m)				
< 1.70	81	14	1.0	1.0
1.70 –	64	10	0.9 (0.4 – 2.2)	0.7 (0.3 – 2.0)
1.75 –	75	14	1.1 (0.5 – 2.4)	0.9 (0.3 – 2.4)
1.80 –	61	7	0.7 (0.3 – 1.7)	0.6 (0.2 – 1.8)
1.85 +	37	8	1.3 (0.5 – 3.2)	1.1 (0.3 – 3.4)
P-value for continuous model			0.907	0.785
BMI (kg/m^2)				
Normal (18.5 – 24.9)	120	20	1.0	1.0
Overweight (25.0 – 29.9)	136	24	1.1 (0.6 – 2.0)	0.9 (0.5 – 1.9)
Obese (30 +)	54	8	0.9 (0.4 – 2.1)	1.1 (0.4 – 2.7)
P-value for continuous model			0.742	0.716
Weekly working hours				
< 40	151	23	1.0	1.0
40 +	171	30	1.2 (0.6 – 2.1)	1.2 (0.7 – 2.3)
P-value for continuous model			0.367	0.324
Length of employment (years)				
< 1	33	7	1.0	1.0
1 –	122	17	0.7 (0.3 – 1.7)	0.6 (0.2 – 1.7)
5 –	63	10	0.7 (0.3 – 2.1)	0.5 (0.1 – 1.4)

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR*[#] *(95% CI)*
10 +	102	18	0.8 (0.3 – 2.2)	0.8 (0.2 – 2.3)
P-value for continuous model			0.719	0.723
Daily Travel time (min.)				
0	35	4	1.0	1.0
1 –	138	24	1.5 (0.5 – 4.7)	1.1 (0.4 – 3.6)
30 –	97	16	1.4 (0.5 – 4.6)	0.8 (0.2 – 2.8)
60 +	52	9	1.5 (0.5 – 5.3)	1.0 (0.3 – 3.7)
P-value for continuous model			0.670	0.825

 # Adjusted for age, gender, and previous LBP

Table 40 ORs for lost time due to LBP for BMI by previous LBP

BMI	*Total number*	*Cases*	*Adjusted OR*[#] *(95% CI)*
LBP during previous 12 months			
No	196	17	1.19 (1.06 – 1.34)**
Yes: work not affected	98	15	0.81 (0.67 – 0.98)*
Yes: lost time	28	21	0.94 (0.78 – 1.12)

ORs represent change in OR for lost time per unit change in BMI
 # Adjusted for age, and gender

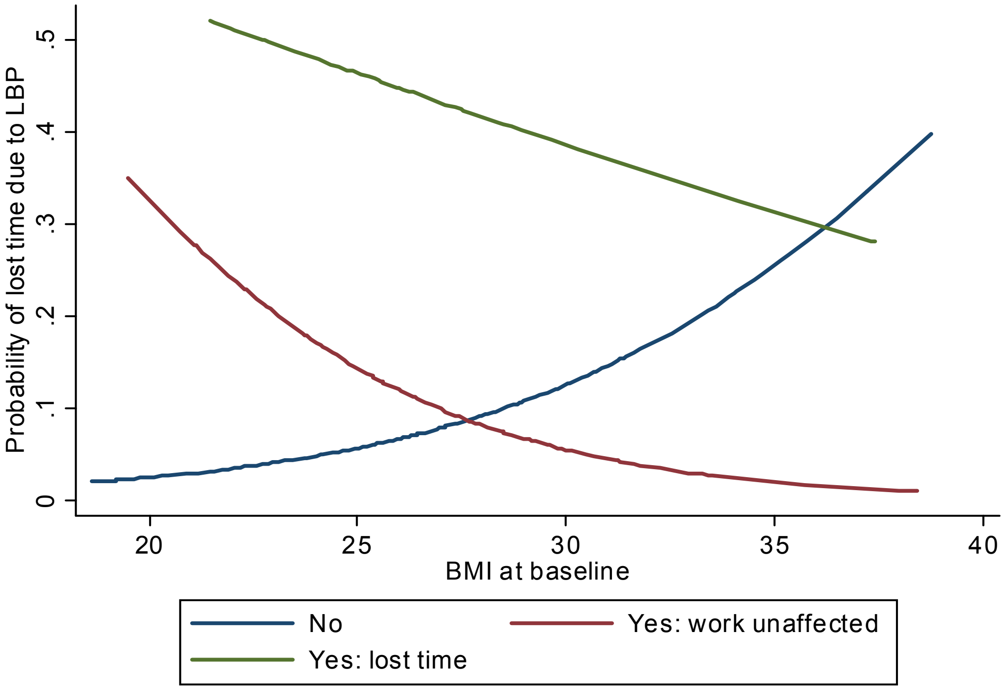


Figure 9 Probability of lost time due to LBP by BMI and previous LBP

Table 41 Crude and adjusted ORs for lost time due to LBP by lifestyle factors

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR*[#] *(95% CI)*
Exercise regularly				
No	126	23	1.0	1.0
Yes	196	30	0.8 (0.5 – 1.5)	0.7 (0.4 – 1.4)
Regularly do aerobic exercise				
No	143	25	1.0	1.0
Yes	179	28	0.9 (0.5 – 1.6)	0.8 (0.4 – 1.5)
Regularly do non-aerobic exercise				
No	269	42	1.0	1.0
Yes	53	11	1.3 (0.6 – 2.7)	1.1 (0.5 – 2.3)
Current smoker				
No	196	26	1.0	1.0
Yes	126	27	1.6 (0.9 – 2.9)	1.5 (0.8 – 2.9)
Number of cigarettes smoked				
< 10	26	3	1.0	1.0
10 –	62	15	2.1 (0.6 – 7.9)	2.0 (0.5 – 8.0)
20 +	37	8	1.9 (0.5 – 7.7)	2.0 (0.4 – 8.7)
P-value for continuous model			0.101	0.103
Smoking duration				
< 20	67	13	1.0	1.0
20 +	47	13	1.4 (0.6 – 3.4)	1.1 (0.3 – 4.2)
P-value for continuous model			0.416	0.872

 # Adjusted for age, gender, and previous LBP

Table 42 Crude and adjusted ORs for lost time due to LBP by psychosocial variables

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR$^{\#}$ (95% CI)*
Influence on and control over work				
[-10, -5]	46	11	1.0	1.0
[-5, 0]	87	17	0.8 (0.4 – 1.9)	0.9 (0.3 – 2.2)
[0, 5]	120	16	0.6 (0.2 – 1.3)	0.8 (0.3 – 1.9)
[5, 10]	58	5	0.4 (0.1 – 1.1)	0.5 (0.1 – 1.7)
P-value for continuous model			0.017*	0.141
Supervisor climate				
[-10, -5]	27	10	1.0	1.0
[-5, 0]	79	16	0.5 (0.2 – 1.3)	0.5 (0.2 – 1.3)
[0, 5]	117	17	0.4 (0.2 – 1.0)*	0.4 (0.2 – 1.1)
[5, 10]	88	6	0.2 (0.1 – 0.6)**	0.2 (0.1 – 0.7)**
P-value for continuous model			0.006**	0.031*
Stimulus from the work itself				
[-10, -5]	47	10	1.0	1.0
[-5, 0]	88	13	0.7 (0.3 – 1.7)	0.9 (0.3 – 2.4)
[0, 5]	105	20	0.9 (0.4 – 2.1)	1.4 (0.5 – 3.4)
[5, 10]	71	6	0.4 (0.1 – 1.2)	0.7 (0.2 – 2.2)
P-value for continuous model			0.114	0.637
Relations with fellow workers				
[-10, -5]	8	1	1.0	1.0
[-5, 0]	46	11	1.9 (0.2 – 16.9)	1.3 (0.1 – 13.5)
[0, 5]	108	19	1.4 (0.2 – 11.9)	1.2 (0.1 – 11.8)
[5, 10]	149	18	1.0 (0.1 – 8.2)	1.2 (0.1 – 10.9)
P-value for continuous model			0.197	0.909
Psychological work load				
[-10, -5]	27	7	1.0	1.0
[-5, 0]	86	15	0.7 (0.2 – 1.8)	0.6 (0.2 – 1.7)
[0, 5]	120	20	0.6 (0.2 – 1.7)	0.7 (0.2 – 1.9)
[5, 10]	78	7	0.3 (0.1 – 1.1)	0.4 (0.1 – 1.3)
P-value for continuous model			0.055	0.211
Management commitment to health and safety				
[-10, -5]	20	6	1.0	1.0
[-5, 0]	66	11	0.6 (0.2 – 1.7)	0.6 (0.2 – 2.1)
[0, 5]	102	21	0.7 (0.2 – 1.9)	0.8 (0.3 – 2.6)
[5, 10]	123	11	0.3 (0.1 – 0.9)*	0.4 (0.1 – 1.4)
P-value for continuous model			0.044*	0.219

 # Adjusted for age, gender, and previous LBP

Table 43 Crude and adjusted ORs for lost time due to LBP if trouble was experienced during the previous three months

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR# (95% CI)*
Neck and shoulders				
No	190	21	1.0	1.0
Yes	125	32	2.3 (1.3 – 4.2)**	1.7 (0.9 – 3.2)
Elbows and wrists/ hands				
No	199	30	1.0	1.0
Yes	119	23	1.3 (0.7 – 2.3)	1.1 (0.6 – 2.0)
Upper back				
No	182	14	1.0	1.0
Yes	140	39	2.3 (1.1 – 4.9)*	1.7 (0.7 – 3.8)
Hips/ thighs/ buttocks, knees and ankles				
No	195	21	1.0	1.0
Yes	123	31	2.3 (1.3 – 4.3)**	1.7 (0.9 – 3.3)

 # Adjusted for age, gender, and if LBP has been experienced in the previous 12 months

Table 44 Crude and adjusted ORs for lost time due to LBP by response to NMQ questions regarding the lower back

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR# (95% CI)*
Lower back				
Trouble during previous three months				
No	249	30	1.0	1.0
Yes	70	22	2.6 (1.4 – 4.8)**	2.6 (1.4 – 4.8)**
Trouble during previous three months				
No	192	14	1.0	1.0
Yes	130	39	4.1 (2.1 – 7.9)**	4.1 (2.1 – 7.9)**
Prevented normal activities				
No	99	20	1.0	1.0
Yes	29	18	3.1 (1.4 – 6.6)**	3.0 (1.4 – 6.4)**
Caused/made worse by job				
No	57	14	1.0	1.0
Yes	70	24	1.4 (0.7 – 2.9)	1.4 (0.7 – 2.9)

 # Adjusted for age and gender

Table 45 Statistics for models including different responses regarding previous LBP

Model	*Log likelihood*	*DF*	*AIC*
Age + gender +			
LBP during previous 12 months (No; Yes, work not affected; Yes, work affected)	-136.39	5	282.79
LBP during previous 12 months (No; Yes)	-144.81	4	297.62
Lower back trouble during previous three months (No; Yes)	-142.31	4	292.62
Lower back trouble during previous seven days (No; Yes)	-145.67	4	299.32

Table 46 Logistic regression final personal variables model for lost time from LBP

Variable	*Adjusted OR# (95% CI)*
Age at entry	0.99 (0.96 – 1.03)
Gender (male/ female)	0.38 (0.11 – 1.34)
Supervisor climate	0.94 (0.88 – 1.00)
LBP during previous 12 months and BMI interaction:	
LBP during previous 12 months (mean BMI)	
No	1.0
Yes: work not affected	1.43 (0.60 – 3.40)
Yes: lost time	7.90 (3.38 – 18.42)**
BMI	
No LBP during previous 12 months	1.17 (1.04 – 1.32)*
LBP during previous 12 months: work not affected	0.85 (0.70 – 1.02)
LBP during previous 12 months: lost time	0.97 (0.80 – 1.17)

Hosmer-Lemeshow goodness of fit statistic for model = 6.39, degrees of freedom=8, P = 0.6034
 # Adjusted for all variables listed

9.6.2 Survival analysis results

Altogether, 515 participants were at risk of absence due to LBP for 227,321 person-days (Table 47). There were 66 episodes of lost time (absence and/or light duties) reported by 53 participants during the study. The estimated survival function for those participants that had experienced a period of lost time due to LBP in the 12 months before the study was statistically significantly different to those who had no LBP before the study ($P < 0.0001$) and those who had experienced LBP but work was not affected ($P < 0.0001$) (Figure 10).

LBP experience before the study was significantly associated with lost time due to LBP during the study period (Table 48). Participants who lost time due to LBP before the study had nearly seven times the risk of experiencing an episode of lost time during the study as those who had no LBP before the study (HR = 6.6, 95% CI 3.5 – 12.2). There was a statistically significant interaction between BMI and LBP experience before the study (P = 0.0009). Those with a higher BMI were at greater risk of lost time during the study if they had not experienced LBP before the study (HR = 1.17, 95% CI 1.06 – 1.28). However, those with a higher BMI were at *lower* risk of lost time if they had experienced LBP before the study that had not affected their work (HR = 0.86, 95% CI 0.76 – 0.99) (Table 49).

Influence and control over work, and supervisor climate showed significant negative association with risk of lost duties due to LBP during the study (Table 50). After adjustment for age, gender and LBP experience before the study supervisor climate remained statistically significant.

Taking any type of regular exercise was associated with a reduced risk of lost time due to LBP (HR = 0.5, 95% CI 0.3 – 0.9) (Table 51). Note that this reduction was not statistically significant when using logistic regression (Table 41).

Those who reported experiencing trouble with the lower back during the previous seven days and the previous three months were at greater risk of lost time due to LBP during the study (seven days: HR = 2.6, 95% CI 1.6 – 5.0; three months: HR = 4.0, 95% CI 2.2 – 7.4) (Table 53). Among those who reported experiencing trouble with the lower back during the previous three months, increased risk of lost time was observed if the trouble prevented normal activities (HR = 2.6, 95% CI 1.4 – 4.8).

The model that included whether the participant experienced lower back trouble during the previous seven days had a lower AIC than using lower back trouble during the previous three months or LBP in the previous 12 months (No; Yes). Again, this is different to that seen using logistic regression. However, the model that included LBP experience during the previous 12 months as a categorical variable (No; Yes, work not affected; Yes, lost time) again had the lowest AIC (Table 54).

The final Cox regression model (before inclusion of the NIOSH parameters) included age, gender, supervisor climate, exercise, and the interaction between BMI and LBP experience. There is no single statistic to assess the goodness-of-fit for a Cox regression model with multiple event data. However, a test based on the Schoenfeld residuals suggests that the proportional-hazards assumption had not been violated by the model (P = 0.3316) (Table 55). Cox-Snell residuals are useful in assessing overall model fit. If the Cox regression model fits the data, these residuals should have a standard exponential distribution with HR = 1. The fit of the model can therefore be verified by estimating the empirical cumulative hazard function with the Cox-Snell residuals as the time variable. If the model fits the data, the plot of the cumulative hazard versus the Cox-Snell residuals should be a straight line with slope 1. For multiple event/record data, the cumulative Cox-Snell residuals are used. Comparing the observed line to the 45°-reference line (Figure 11) suggests that the Cox model fits the data reasonably well. Note that some variability about the 45° line is expected, particularly in the right-hand tail, due to the changes in the effective sample size caused by censoring.

Table 47 Descriptive statistics for survival-time data: lost time due to LBP

	Total	***Per subject***			
		mean	***min***	***median***	***max***
Number of subjects	515				
Time to exit (days)		444.49	1	548	644
Subjects with lost time	53				
Days lost (N = 53)	1,691	31.91	1	15	410
Days at risk	227,321	441.40	1	548	644
Cases	66	0.13	0	0	3

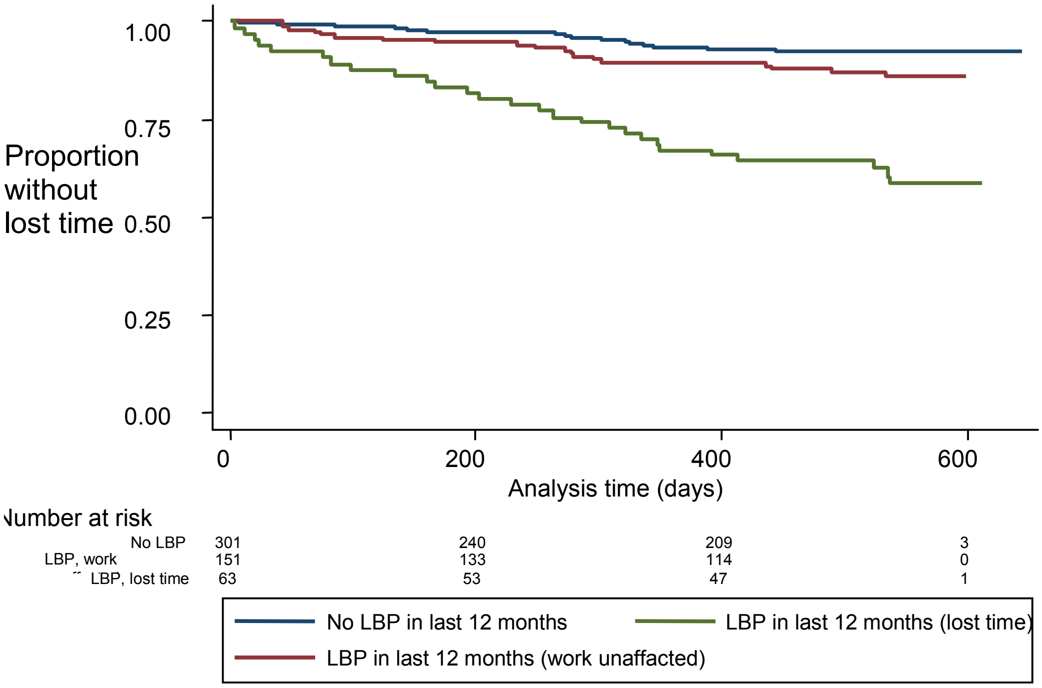


Figure 10 Kaplan-Meier survival estimates for lost time due to LBP by previous LBP

Table 48 Unadjusted and adjusted HRs for lost time due to LBP by personal variables

	Days at risk	*Cases*	*HR (95% CI)*	*HR$^{\#}$ (95% CI)*
LBP during previous 12 months				
No	128,925	19	1.0	
Yes: work not affected	69,457	19	1.9 (0.9 – 3.8)	
Yes: lost time	28,939	28	6.6 (3.5 – 12.2)**	
P-value for continuous model			< 0.0001**	
Gender				
Male	183,428	58	1.0	
Female	43,893	8	0.6 (0.3 – 1.2)	
Age at entry (years)				
< 30	41,966	11	1.0	
30 –	82,661	22	1.0 (0.5 – 2.1)	
40 +	102,127	33	1.2 (0.6 – 2.5)	
P-value for continuous model			0.446	
Weight (kg)				
< 70	58,694	16	1.0	1.0
70 –	58,959	17	1.1 (0.5 – 2.3)	0.8 (0.4 – 1.7)
80 –	55,453	21	1.4 (0.7 – 2.9)	1.1 (0.6 – 2.3)
90 +	48,629	11	0.8 (0.4 – 1.9)	0.6 (0.3 – 1.4)
P-value for continuous model			0.607	0.828
Height (m)				
< 1.70	59,745	16	1.0	1.0
1.70 –	45,281	15	1.2 (0.5 – 2.8)	0.9 (0.4 – 2.0)
1.75 –	50,517	14	1.0 (0.5 – 2.1)	0.7 (0.3 – 1.6)
1.80 –	42,309	12	1.1 (0.4 – 2.7)	0.8 (0.3 – 2.2)
1.85 +	27,339	9	1.2 (0.5 – 2.9)	0.9 (0.4 – 2.2)
P-value for continuous model			0.684	0.574
BMI (kg/m^2)				
Normal (18.5 – 24.9)	87,418	24	1.0	1.0
Overweight (25.0 – 29.9)	95,122	32	1.2 (0.7 – 2.3)	1.0 (0.6 – 1.8)
Obese (30 +)	37,065	9	0.9 (0.4 – 2.0)	1.0 (0.4 – 2.2)
P-value for continuous model			0.748	0.923
Weekly working hours				
< 40	103,434	26	1.0	1.0
40 +	123,887	40	1.3 (0.7 – 2.2)	1.2 (0.7 – 2.1)
P-value for continuous model			0.070	0.132
Length of employment (years)				
< 1	26,710	11	1.0	1.0
1 –	82,507	17	0.5 (0.2 – 1.3)	0.5 (0.2 – 1.0)
5 –	41,582	11	0.7 (0.2 – 1.8)	0.4 (0.1 – 1.1)
10 +	74,336	25	0.8 (0.3 – 2.1)	0.6 (0.2 – 1.5)

	Days at risk	***Cases***	***HR (95% CI)***	***HR# (95% CI)***
P-value for continuous model			0.364	0.731
Daily Travel time (min.)				
0	20,643	4	1.0	1.0
1 –	97,181	31	1.7 (0.6 – 4.6)	1.1 (0.4 – 3.0)
30 –	70,731	19	1.4 (0.5 – 4.0)	0.7 (0.2 – 2.1)
60 +	38,766	12	1.6 (0.5 – 5.2)	0.9 (0.3 – 2.6)
P-value for continuous model			0.956	0.555

 # HRs adjusted for age, gender, and if previous LBP

Table 49 HRs for lost time due to LBP for BMI by previous LBP

BMI	***Days at risk***	***Cases***	***Adjusted HR# (95% CI)***
LBP during previous 12 months			
No	128,925	19	1.17 (1.06 – 1.28)**
Yes: work not affected	69,457	19	0.86 (0.76 – 0.99)*
Yes: lost time	28,939	28	0.94 (0.84 – 1.05)

HRs represent change in HR for lost time per unit change in BMI
 # Adjusted for age, and gender

Table 50 Unadjusted and adjusted HRs for lost time due to LBP by psychosocial variables

	Days at risk	*Cases*	*HR (95% CI)*	*Adjusted HR*$^{\#}$ *(95% CI)*
Influence on and control over work				
[-10, -5]	35,853	17	1.0	1.0
[-5, 0]	63,996	22	0.7 (0.3 – 1.6)	0.8 (0.4 – 1.6)
[0, 5]	80,910	17	0.4 (0.2 – 1.0)*	0.6 (0.3 – 1.2)
[5, 10]	37,808	6	0.3 (0.1 – 1.0)*	0.5 (0.2 – 1.4)
P-value for continuous model			0.009**	0.101
Supervisor climate				
[-10, -5]	22,280	13	1.0	1.0
[-5, 0]	56,577	21	0.6 (0.3 – 1.5)	0.6 (0.3 – 1.3)
[0, 5]	83,633	20	0.4 (0.2 – 0.9)*	0.5 (0.2 – 1.0)*
[5, 10]	56,077	8	0.2 (0.1 – 0.7)**	0.3 (0.1 – 0.8)*
P-value for continuous model			0.013*	0.038*
Stimulus from the work itself				
[-10, -5]	36,784	15	1.0	1.0
[-5, 0]	60,178	13	0.5 (0.2 – 1.2)	0.7 (0.3 – 1.5)
[0, 5]	73,867	25	0.8 (0.4 – 1.8)	1.2 (0.6 – 2.5)
[5, 10]	47,738	9	0.5 (0.2 – 1.3)	0.8 (0.3 – 2.3)
P-value for continuous model			0.244	0.917
Relations with fellow workers				
[-10, -5]	5,154	2	1.0	1.0
[-5, 0]	34,003	13	1.0 (0.1 – 6.7)	0.7 (0.2 – 2.9)
[0, 5]	78,031	23	0.8 (0.1 – 5.1)	0.7 (0.2 – 2.7)
[5, 10]	101,379	24	0.6 (0.1 – 4.1)	0.8 (0.2 – 3.0)
P-value for continuous model			0.468	0.701
Psychological work load				
[-10, -5]	20,258	7	1.0	1.0
[-5, 0]	61,000	21	1.0 (0.4 – 2.3)	0.9 (0.4 – 2.0)
[0, 5]	86,741	24	0.8 (0.4 – 1.8)	1.0 (0.5 – 2.0)
[5, 10]	50,568	10	0.6 (0.2 – 1.6)	0.7 (0.3 – 1.9)
P-value for continuous model			0.108	0.530
Management commitment to health and safety				
[-10, -5]	17,218	9	1.0	1.0
[-5, 0]	45,974	12	0.5 (0.2 – 1.4)	0.6 (0.2 – 1.6)
[0, 5]	77,178	27	0.7 (0.3 – 1.8)	0.8 (0.4 – 1.9)
[5, 10]	78,197	14	0.3 (0.1 – 1.0)*	0.5 (0.2 – 1.4)
P-value for continuous model			0.074	0.295

 # Adjusted for age, gender, and previous LBP

Table 51 Unadjusted and adjusted HRs for lost time due to LBP by lifestyle factors

	Days at risk	*Cases*	*HR (95% CI)*	*Adjusted HR$^{\#}$ (95% CI)*
Exercise regularly				
No	90,458	34	1.0	1.0
Yes	136,863	32	0.6 (0.4 – 1.1)	0.5 (0.3 – 0.9)*
Regularly do aerobic exercise				
No	101,689	36	1.0	1.0
Yes	125,632	30	0.7 (0.4 – 1.2)	0.6 (0.4 – 1.0)
Regularly do non-aerobic exercise				
No	188,855	54	1.0	1.0
Yes	38,466	12	1.1 (0.6 – 2.1)	0.9 (0.5 – 1.7)
Current smoker				
No	137,951	32	1.0	1.0
Yes	89,370	34	1.6 (0.9 – 2.9)	1.6 (0.9 – 2.8)
Number of cigarettes smoked				
< 10	17,619	3	1.0	1.0
10 –	45,536	20	2.6 (0.8 – 8.7)	2.3 (0.6 – 8.4)
20 +	24,992	9	2.1 (0.6 – 7.6)	1.9 (0.5 – 7.0)
P-value for continuous model			0.066	0.103
Smoking duration				
< 20	46,133	14	1.0	1.0
20 +	36,453	19	1.7 (0.8 – 3.7)	0.9 (0.4 – 2.1)
P-value for continuous model			0.094	0.729

 # Adjusted for age, gender, and previous LBP

Table 52 Unadjusted and adjusted HRs for lost time due to LBP if trouble was experienced during the previous three months

	Days at risk	*Cases*	*HR (95% CI)*	*Adjusted HR# (95% CI)*
Neck and shoulders				
No	128,956	27	1.0	1.0
Yes	94,148	39	2.0 (1.1 – 3.5)*	1.3 (0.7 – 2.2)
Elbows and wrists/ hands				
No	168,288	46	1.0	1.0
Yes	54,141	19	1.3 (0.7 – 2.5)	1.1 (0.6 – 1.9)
Upper back				
No	194,065	48	1.0	1.0
Yes	12,510	15	2.2 (1.2 – 4.0)*	1.5 (0.9 – 2.8)
Hips/ thighs/ buttocks, knees & ankles				
No	129,506	23	1.0	1.0
Yes	94,601	40	2.4 (1.4 – 4.1)**	1.7 (1.0 – 3.0)

 # Adjusted for age, gender, and LBP experience in the previous 12 months

Table 53 Unadjusted and adjusted HRs for lost time due to LBP by response to NMQ questions regarding the lower back

	Days at risk	*Cases*	*HR (95% CI)*	*Adjusted HR[#] (95% CI)*
Lower back				
Trouble during previous seven days				
No	123,944	15	1.0	1.0
Yes	102,584	51	4.1 (2.2 – 7.6)**	2.9 (1.6 – 5.0)**
Trouble during previous three months				
No	171,341	34	1.0	1.0
Yes	53,207	31	3.0 (1.7 – 5.2)**	4.0 (2.2 – 7.4)**
Prevented normal activities				
No	70,525	23	1.0	1.0
Yes	30,186	27	2.7 (1.5 – 5.1)**	2.6 (1.4 – 4.8)**
Caused/made worse by job				
No	44,602	15	1.0	1.0
Yes	56,100	35	1.8 (1.0 – 3.5)	1.8 (1.0 – 3.5)

 # Adjusted for age and gender

Table 54 Statistics for Cox regression models including different responses regarding previous LBP

Model	*Log likelihood*	*DF*	*AIC*
Age + gender +			
LBP during previous 12 months (No; Yes, work not affected; Yes, work affected)	-377.43	4	762.85
LBP during previous 12 months (No; Yes)	-386.55	3	779.06
Lower back trouble during previous three months (No; Yes)	-382.87	3	771.74
Lower back trouble during last seven days (No; Yes)	-381.26	3	768.52

Table 55 Cox regression final personal variables model for lost time from LBP

Variable	*Adjusted HR$^{\#}$ (95% CI)*
Age at entry	1.01 (0.98 – 1.04)
Gender (male/ female)	0.23 (0.07 – 0.75)*
Supervisor climate	0.95 (0.90 – 1.00)
Exercise regularly (No; Yes)	0.47 (0.28 – 0.79)**
LBP during previous 12 months and BMI interaction:	
LBP during previous 12 months (mean BMI)	
No	1.00
Yes: work not affected	1.60 (0.71 – 3.58)
Yes: lost time	6.55 (3.34 – 12.82)**
BMI	
No LBP during previous 12 months	1.13 (1.03 – 1.24)**
LBP during previous 12 months: work not affected	0.89 (0.78 – 1.00)*
LBP during previous 12 months: lost time	0.94 (0.85 – 1.04)

Test of proportional hazards assumption for model: $\chi^2 = 10.24$*, degrees of freedom = 9, P = 0.3316*

 # Adjusted for all variables shown

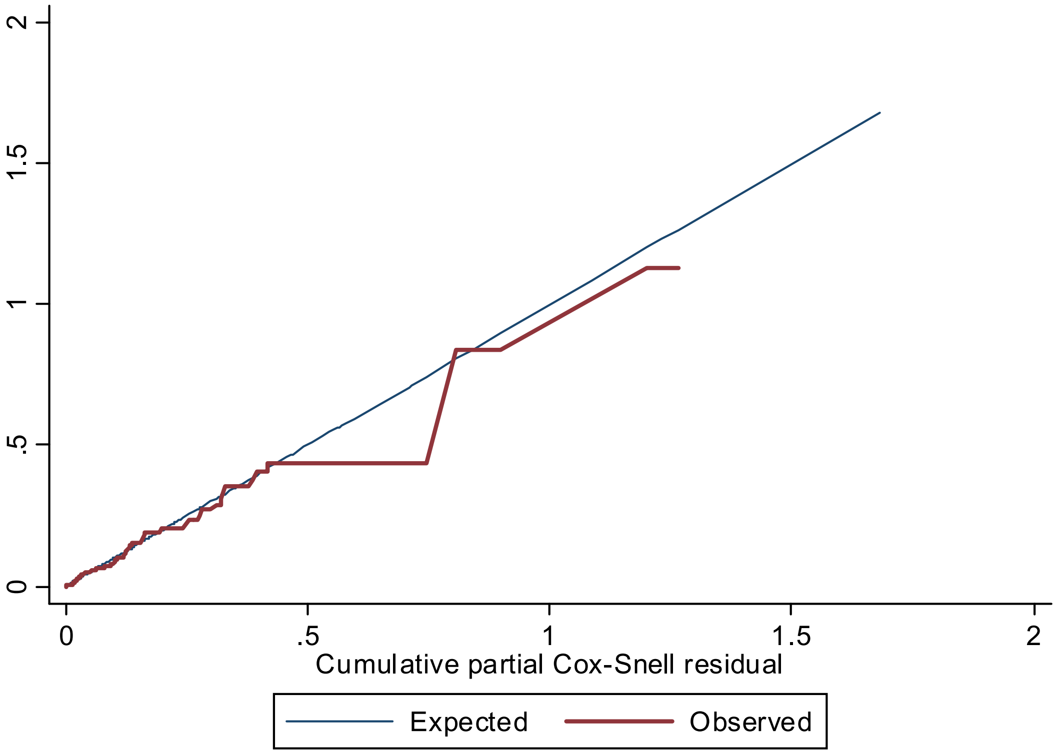


Figure 11 Cumulative hazard of Cox-Snell residuals for final Cox regression model

9.7 DURATION OF LOST TIME DUE TO LBP

Altogether, 53 participants lost 1,691 days of full work duties due to LBP (Table 56). There were 66 episodes of lost time (absence and/or light duties), two of which had not returned to full duties by the end of the study period. The mean time to return to full duties was 26 days, with a median of 9.5 days. For comparison, the 2006/07 Labour Force Survey found that "on average" individuals with a work-related MSD mainly affecting the back took 16.8 days off work (Health and Safety Executive, 2008). The AIC associated with the log–normal and generalised gamma AFT models were the smallest (AIC = 228.9) (Table 57). The log–normal model is nested within the gamma model and is analogous to linear regression with the logarithm of time as the outcome measure, and so was selected as the preferred model.

Those who had experienced LBP that did not affect their work in the 12 months before the study had a statistically significantly greater duration of lost time than either those who had not experienced LBP (TR = 2.2, 95% CI 1.0 – 4.9) (Table 58) or had lost time due to LBP. There was no statistically significant difference between these two groups. There was a statistically significant trend of increasing duration of lost time with increasing BMI (P = 0.021). Those who were classed as obese had three times the duration of lost time as compared to those classed as having normal BMI, but those who were overweight were not significantly different to those with normal BMI. While neither age nor weekly working hours had a significant effect, there was a significant interaction between the two (P = 0.0365). For example, the duration of lost time decreased at older ages for those who worked 35 hours a week (TR = 0.95, 95% CI 0.91 – 1.00) (Figure 12). However, the duration of lost time non-significantly increased at older ages for those who worked 50 hours a week (TR = 1.03, 95% CI 0.98 – 1.08).

There were no statistically significant lifestyle factors (Table 59). There was a statistically significant interaction between smoking status and age (P = 0.0001). Those who were not current smokers showed an increase in duration of lost time with increasing age (TR = 1.04, 95% CI 1.00 – 1.08). Those who were current smokers showed a decrease in duration of lost time with increasing age (TR = 0.93, 95% CI 0.89 – 0.96) (Figure 13).

There were no statistically significant associations between the psychosocial variables and duration of lost time (Table 60). However, for all but "Influence and control over work", there were significant interactions with age. For example, there was a statistically significant interaction between the score for "Relations with fellow workers" and age (P = 0.0012). There was a decrease in duration of lost time with increasing age for those with a zero score (TR = 0.95, 95% CI 0.91 – 0.98). Those who reported a positive score for "Relations with fellow workers" (a score of 8 in Figure 14) showed a non-significant increase in duration of lost time with increasing age (TR = 1.03, 95% CI 0.98 – 1.07). Similar results were observed for the other interactions of the psychosocial variables and age (not shown).

There were no significant associations found between the NMQ responses and duration of lost time (Table 61), including the questions specific to the lower back (Table 62). As mentioned above, the variables relating to the participants' LBP experience before the study (12 months, three months or seven days) were not significant overall in predicting the duration of lost time due to LBP. The AIC values after adjustment for age and gender are relatively close to one another and so cannot be differentiated (Table 63).

The final log–normal AFT model included gender, LBP experience, BMI, the interaction between age and the "Relations with fellow workers" psychosocial variable, and the interaction between age and smoking status (Table 64). Comparing the Cox-Snell residuals to the 45° reference line suggests that the AFT model is an acceptable fit (Figure 15).

Table 56 Duration of lost time due to LBP

	Total	*Mean*	*Min*	*Median*	*Max*
Number of subjects	53				
Number of periods of lost time	66				
Return to work	64				
Duration of lost time (days)	1,691	25.62	1	9.5	410

Table 57 Comparison of AIC values for various AFT models

Distribution (with covariates of age, gender and LBP experience for all models)	*Log likelihood*	*DF*	*AIC*
Exponential	-121.79	5	253.58
Weibull	-116.27	6	244.53
Log-normal	-108.44	6	228.87
Log-logistic	-108.85	6	229.70
Generalised gamma	-107.43	7	228.86

Table 58 TRs for returning to full duties after starting a period of lost time due to LBP by personal variables, estimated using AFT models

	Days of lost time	*Return to full duties*	*Median return time*	*TR (95% CI)*	*Adjusted TR# (95% CI)*
LBP during previous 12 months					
No	240	19	9.0	1.0	
Yes: work not affected	294	18	18.0	2.2 (1.0 – 4.9)*	
Yes: lost time	757	27	9.0	1.0 (0.5 – 2.2)	
P-value for trend				0.919	
Gender					
Male	1,458	56	9.5	1.0	
Female	233	8	10.5	1.1 (0.5 – 2.9)	
Age (years)					
< 30	624	11	18.0	1.0	
30 –	436	21	10.5	0.6 (0.2 – 1.7)	
40 +	631	32	7.0	0.5 (0.2 – 1.5)	
P-value for continuous model				0.553	
Weight (kg)					
< 70	811	15	16.5	1.0	1.0
70 –	251	17	10.0	0.8 (0.3 – 2.2)	0.9 (0.4 – 2.4)
80 –	451	20	7.0	0.7 (0.2 – 1.9)	0.8 (0.3 – 1.9)
90 +	170	11	14.0	0.9 (0.3 – 2.4)	1.3 (0.4 – 4.4)
P-value for continuous model				0.767	0.317
Height (m)					
< 1.70	773	16	13.5	1.0	1.0
1.70 –	414	14	7.0	0.8 (0.3 – 2.2)	0.7 (0.2 – 2.3)
1.75 –	219	14	6.0	0.5 (0.2 – 1.4)	0.4 (0.1 – 1.4)

	Days of lost time	***Return to full duties***	***Median return time***	***TR (95% CI)***	***Adjusted TR*** $^{\#}$ ***(95% CI)***
1.80 –	170	11	9.5	0.6 (0.2 – 1.7)	0.4 (0.1 – 1.4)
1.85 +	115	9	14.0	0.7 (0.3 – 1.7)	0.5 (0.1 – 1.8)
P-value for continuous model				0.508	0.349
BMI (kg/m ^{2} ***)***					
Normal (18.5 – 24.9)	951	23	14.0	1.0	1.0
Overweight (25.0 – 29.9)	543	31	7.0	0.6 (0.3 – 1.3)	0.9 (0.4 – 2.0)
Obese (30 +)	189	9	15.0	1.2 (0.5 – 3.0)	3.1 (1.1 – 8.4)*
P-value for continuous model				0.396	0.021*
Weekly working hours					
< 40	801	23	13.5	1.0	1.0
40 +	890	38	8.0	0.9 (0.4 – 1.7)	0.8 (0.4 – 1.5)
P-value for continuous model				0.447	0.491
Length of employment (years)					
< 1	159	11	11.0	1.0	1.0
1 –	774	17	8.0	1.1 (0.4 – 3.5)	0.9 (0.3 – 2.6)
5 –	198	10	15.0	1.1 (0.4 – 3.1)	1.4 (0.7 – 2.8)
10 +	491	24	7.0	1.0 (0.4 – 2.3)	1.4 (0.7 – 3.1)
P-value for continuous model				0.981	0.198
Daily Travel time (min.)					
0	268	4	45.5	1.0	1.0
1 –	468	30	11.0	0.2 (0.1 – 0.7)**	0.3 (0.1 – 0.7)**
30 –	829	18	6.0	0.2 (0.1 – 0.8)*	0.3 (0.1 – 1.2)
60 +	126	12	7.0	0.2 (0.05 – 0.5)**	0.2 (0.1 – 0.9)
P-value for continuous model				0.029*	0.264

 # Adjusted for age, gender, and previous LBP

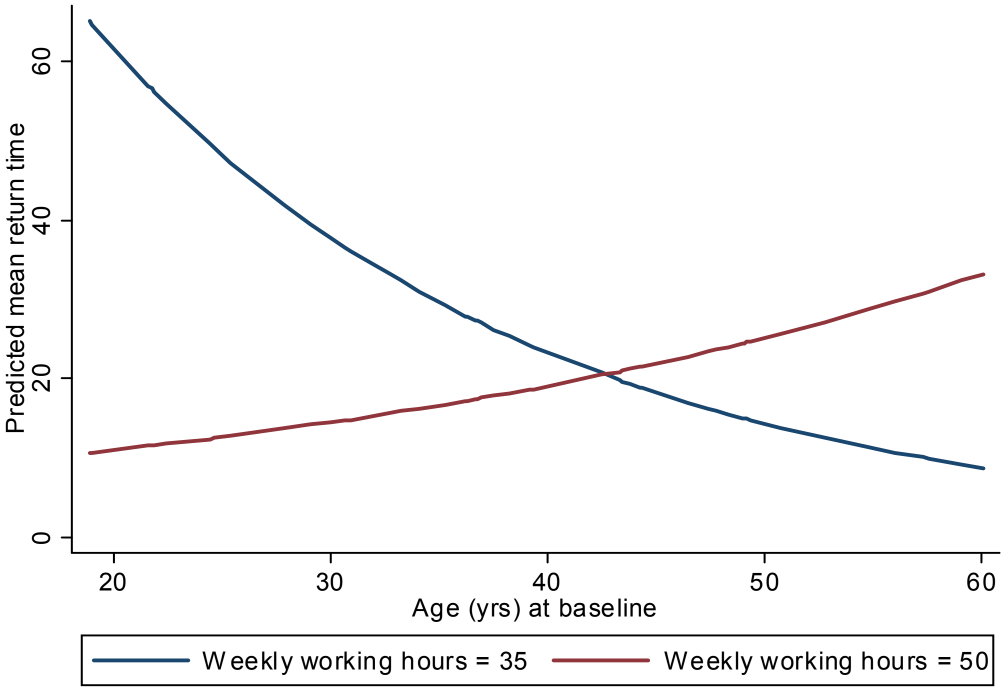


Figure 12 **Mean time to return to full duties after starting a period of lost time due to LBP by age and weekly working hours, predicted using AFT models**

Table 59 TRs for returning to full duties after starting a period of lost time due to LBP by lifestyle factors, estimated using AFT models

	Days of lost time	*Return to full duties*	*Median return time*	*TR (95% CI)*	*Adjusted TR[#] (95% CI)*
Exercise regularly					
No	430	33	7.0	1.0	1.0
Yes	1,261	31	16.5	1.7 (0.9 – 3.2)	1.7 (0.9 – 3.1)
Regularly do aerobic exercise					
No	858	35	7.0	1.0	1.0
Yes	833	29	14.0	0.4 (0.2 – 1.0)	1.2 (0.6 – 2.4)
Regularly do non-aerobic exercise					
No	1,151	52	9.5	1.0	1.0
Yes	540	12	11.5	1.0 (0.4 – 2.5)	0.9 (0.4 – 2.3)
Current smoker					
No	682	31	11.5	1.0	1.0
Yes	1,009	33	7.5	1.0 (0.5 – 1.9)	0.8 (0.4 – 1.5)
Number of cigarettes smoked					
< 10	183	3	20.0	1.0	1.0
10 –	614	20	7.0	0.6 (0.05 – 7.1)	2.2 (0.2 – 21.3)
20 +	196	9	18.0	0.9 (0.1 – 10.8)	3.4 (0.4 – 27.4)
P-value for continuous model				0.864	0.803
Smoking duration (years)					
< 20	802	13	16.5	1.0	1.0
20 +	199	19	7.0	0.4 (0.2 – 1.0)	1.8 (0.9 – 3.7)
P-value for continuous model				0.044*	0.059

 # Adjusted for age, gender, and previous LBP

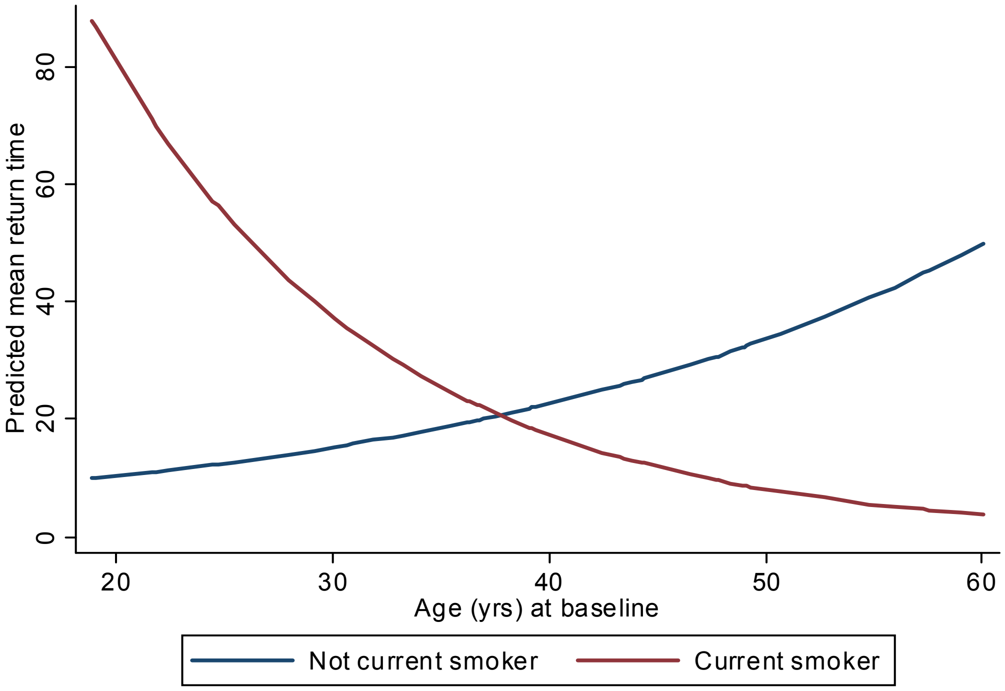


Figure 13 Mean time to return to full duties after starting a period of lost time due to LBP by age and smoking status, predicted using AFT models

Table 60 TRs for returning to full duties after starting a period of lost time due to LBP by psychosocial variables, estimated using AFT models

	Days of lost time	*Return to full duties*	*Median return time*	*TR (95% CI)*	*Adjusted TR*[#] *(95% CI)*
Influence on and control over work					
[-10, -5]	407	17	8.0	1.0	1.0
[-5, 0]	276	21	7.0	0.8 (0.3 – 1.7)	0.6 (0.3 – 1.5)
[0, 5]	810	16	11.0	1.2 (0.4 – 3.5)	1.1 (0.4 – 3.0)
[5, 10]	141	6	25.5	1.6 (0.4 – 5.7)	1.8 (0.5 – 6.5)
P-value for continuous model				0.087	0.070
Supervisor climate					
[-10, -5]	501	11	10.0	1.0	1.0
[-5, 0]	704	21	8.0	0.9 (0.3 – 3.0)	0.6 (0.2 – 1.9)
[0, 5]	293	20	9.5	0.7 (0.2 – 2.2)	0.6 (0.2 – 1.4)
[5, 10]	136	8	15.5	1.0 (0.3 – 3.8)	1.0 (0.3 – 3.5)
P-value for continuous model				0.874	0.892
Stimulus from the work itself					
[-10, -5]	178	15	7.0	1.0	1.0
[-5, 0]	639	13	17.0	1.6 (0.6 – 4.6)	1.1 (0.4 – 3.2)
[0, 5]	596	23	9.0	1.2 (0.6 – 2.4)	0.8 (0.4 – 1.7)
[5, 10]	221	9	27.0	2.4 (1.0 – 5.9)*	2.2 (0.8 – 5.7)
P-value for continuous model				0.394	0.436
Relations with fellow workers					
[-10, -5]	11	2	5.5	1.0	1.0
[-5, 0]	577	13	8.0	2.2 (1.1 – 4.5)*	1.5 (0.6 – 3.6)
[0, 5]	472	23	8.0	1.4 (0.8 – 2.6)	1.3 (0.7 – 2.5)
[5, 10]	574	22	14.5	2.2 (1.3 – 3.7)**	1.5 (0.7 – 3.1)
P-value for continuous model				0.402	0.649
Psychological work load					
[-10, -5]	126	7	14.0	1.0	1.0
[-5, 0]	666	19	8.0	1.1 (0.3 – 3.5)	0.7 (0.2 – 2.0)
[0, 5]	627	24	7.0	0.8 (0.3 – 2.3)	0.6 (0.2 – 1.5)
[5, 10]	215	10	17.5	1.7 (0.6 – 5.2)	1.1 (0.3 – 3.7)
P-value for continuous model				0.925	0.681
Management commitment to health and safety					
[-10, -5]	128	9	6.0	1.0	1.0
[-5, 0]	881	11	9.0	2.7 (0.7 – 10.5)	2.1 (0.5 – 8.8)
[0, 5]	441	27	12.0	1.3 (0.5 – 3.5)	1.1 (0.4 – 2.9)
[5, 10]	184	13	9.0	1.1 (0.4 – 3.4)	1.2 (0.3 – 4.4)
P-value for continuous model				0.462	0.501

 # Adjusted for age, gender, and previous LBP

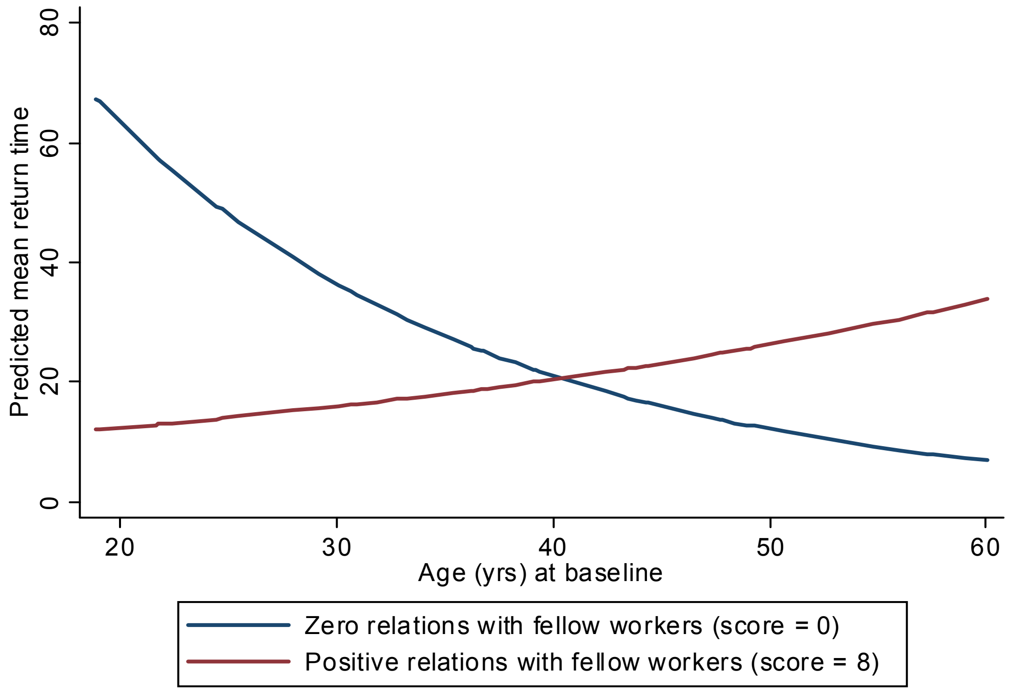


Figure 14 Mean time to return to full duties after a period of lost time due to LBP by age and relations with fellow workers, predicted using AFT models

Table 61 TRs for returning to full duties after a period of lost time due to LBP if trouble was experienced during the previous three months, estimated using AFT models

	Days of lost time	*Return to full duties*	*Median return time*	*TR (95% CI)*	*Adjusted TR[#] (95% CI)*
Neck and shoulders					
No	748	27	10.0	1.0	1.0
Yes	943	37	8.0	1.2 (0.6 – 2.4)	1.1 (0.6 – 2.2)
Elbows and wrists/ hands					
No	914	35	10.5	1.0	1.0
Yes	777	29	7.5	0.9 (0.5 – 1.8)	0.8 (0.5 – 1.6)
Upper back					
No	1,291	48	7.0	1.0	1.0
Yes	389	13	11.5	0.8 (0.3 – 1.8)	0.7 (0.3 – 1.6)
Hips/ thighs/ buttocks, knees and ankles					
No	748	23	18.5	1.0	1.0
Yes	935	38	7.5	1.0 (0.5 – 1.9)	0.8 (0.4 – 1.6)

 # Adjusted for age, gender, and previous LBP

Table 62 TRs for returning to full duties after a period of lost time due to LBP by response to NMQ questions regarding the lower back, estimated using AFT models

	Days of lost time	*Return to full duties*	*Median return time*	*TR (95% CI)*	*Adjusted TR[#] (95% CI)*
Lower back					
Trouble during last seven days					
No	837	34	9.5	1.0	1.0
Yes	810	29	8.0	1.5 (0.8 – 2.8)	1.5 (0.8 – 2.8)
Trouble during previous three months					
No	144	15	9.0	1.0	1.0
Yes	1,547	49	11.0	1.6 (0.9 – 2.9)	1.9 (1.0 – 3.8)
Prevented normal activities					
No	921	23	16.0	1.0	1.0
Yes	582	25	7.0	0.7 (0.3 – 1.4)	0.7 (0.3 – 1.6)
Caused/made worse by job					
No	798	15	20.0	1.0	1.0
Yes	705	33	7.0	0.6 (0.2 – 1.6)	0.7 (0.2 – 2.1)

 # Adjusted for age and gender

Table 63 Comparison of AIC values for AFT models of return to full duties

Model	*Log likelihood*	*DF*	*AIC*
Age + gender +			
LBP during previous 12 months (No; Yes, work not affected; Yes, work affected)	-108.44	6	228.87
LBP during previous 12 months (No; Yes)	-110.43	5	230.85
Lower back trouble during previous three months (No; Yes)	-109.79	5	229.59
Lower back trouble during previous seven days (No; Yes)	-108.60	5	227.19

Table 64 Final personal variables model for time to return to full duties after starting a period of lost time due to LBP using AFT models

Variable	*Adjusted TR$^{\#}$ (95% CI)*
Gender (male/ female)	0.74 (0.18 – 3.08)
LBP during previous 12 months:	
No	1.00
Yes: work not affected	4.59 (1.97 – 10.70)**
Yes: lost time	0.94 (0.45 – 1.94)
BMI	1.04 (0.96 – 1.13)
Age and relations with fellow workers interaction:	
Age (zero relations with workers, not current smoker)	1.06 (0.95 – 1.18)
Relations with fellow workers (mean age)	0.98 (0.93 – 1.03)
Interaction term	1.01 (1.00 – 1.01)*
Age and smoking status interaction:	
Current smoker (No; Yes) (mean age)	0.66 (0.38 – 1.12)
Interaction term	0.92 (0.87 – 0.97)**

 # Adjusted for all variables listed

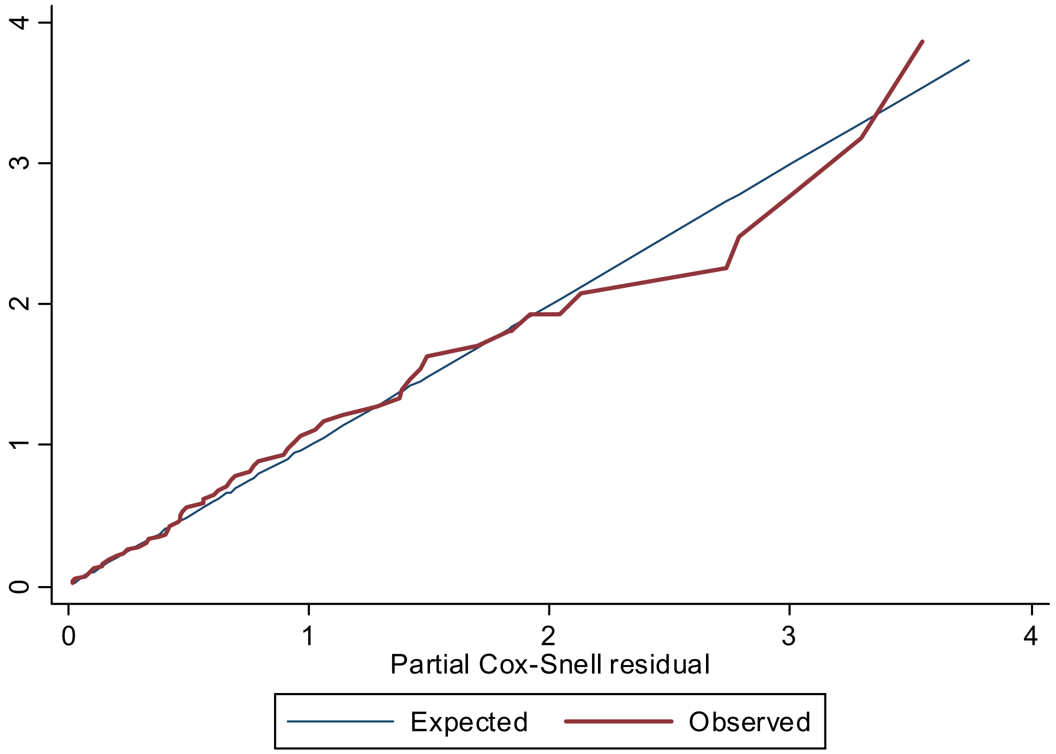


Figure 15 Cumulative hazard of Cox-Snell residuals for final AFT models

9.8 DAYS LOST DUE TO LBP – CLI, MAXIMUM STLI AND TASK VARIABLES

Descriptive statistics are presented by question 12 of the baseline questionnaire: “Have you suffered from low back pain during the last 12 months?” Due to the non-normality of the data the medians with interquartile ranges are given, with group comparisons of continuous variables performed using the Kruskal-Wallis test. There were statistically significant differences in the STLI between previous LBP experience groups (Table 65). Those who had not experienced LBP in the 12 months leading up to the study had a median STLI of 2.1 (interquartile range 1.4 – 3.5), with those who had lost work time due to LBP having a median value of 1.5 (interquartile range 1.1 – 3.5). This may indicate some kind of healthy worker effect may have affected the distribution of workers across jobs.

The numbers of cases of lost time due to LBP were insufficient for logistic regression with CLI ≤ 1 (n = 3), and possibly also logistic regression with STLI ≤ 1 (n = 7) and Cox regression with CLI ≤ 1 (n = 6). The only significant results were seen for STLI during the GEE analysis (STLI > 1 vs. STLI ≤ 1: OR = 0.5, 95% CI 0.2 – 0.8; test for trend, P = 0.02). However, these were crude ORs and adjustment for the basic personal variables led to the results no longer being statistically significant.

Figure 16 shows the incidence of lost time during the study by CLI and STLI, neither of which displays any obvious trend. Table 66, Table 67 and Table 68 show the results obtained from logistic regression, Cox regression and GEEs for CLI and STLI.

The results of investigating the task variables involved in calculating the maximum STLI are shown in Table 69, Table 70 and Table 71. There were no statistically significant associations with lost time due to LBP for the task variables in the logistic regression (Table 69). There was a statistically significant interaction between age and the vertical offset of the hands from 750 mm (P = 0.04). This was shown by there being no significant association with vertical offset for those who were 30 years of age (P = 0.53). However, for every 100 mm increase in vertical offset, the odds of lost time increased by 28% for those who were 50 years of age (OR = 1.28, 95% CI 1.02 – 1.59; Figure 17).

For the Cox regression, there was a statistically significant association between the maximum horizontal location of the hands and lost time due to LBP (Table 70). The risk of lost time for those who held the load more than 900 mm away was over three times the risk for those who held the load less than 500 mm away (HR = 3.7, 95% CI 1.1 – 12.3). There was a statistically significant linear trend, with a 100 mm increase in horizontal location of the hands resulting in a 25% increase in risk of lost time due to LBP (OR = 1.25, 95% CI 1.04 – 1.49). There was also a statistically significant increasing trend for the maximum vertical offset of the hands from a height of 750 mm, but this was no longer significant once personal variables were controlled for (Table 70). There were statistically significant interactions between age and the horizontal location of the hands (P = 0.03), the vertical location of the hands (P = 0.01) and the lifting frequency (P < 0.001). For example, at 50 years of age there was a statistically significant trend of increasing risk of lost time with increasing horizontal location (P < 0.0001) and vertical location (P < 0.01). However, these trends were not statistically significant for those at 30 years of age (Figure 18 and Figure 19). There was also a statistically significant interaction between age and lifting frequency (P < 0.01). For example, there was a 46% reduction in risk of lost time with an increase of one lift per minute for those aged 30 years (HR = 0.54, 95% CI 0.33 – 0.90), but there was a 29% increase in risk for those aged 50 years (HR = 1.29, 95% CI 1.12 – 1.50) (Figure 20).

For the GEE analysis, there was a statistically significant increase in the odds of reporting LBP during the study if the coupling type was fair or good, as compared to poor coupling (OR = 2.5, 95% CI 1.3 – 4.9; Table 71). There were statistically significant interactions between age and the maximum load weight (P = 0.01), and the horizontal location of the hands (P = 0.03). For example, there were no statistically significant trends in odds of reporting LBP for load weight or horizontal location for those who were 30 years of age. However, for those who were 50 years of age, the odds decreased with increasing load weight (P < 0.01), but increased with increasing horizontal distance (P = 0.03) (Figure 21 and Figure 22). The effect of vertical location of the hands on the odds of reporting LBP also varied by body weight (P = 0.02). For example, there was no significant association between reporting LBP and the vertical location for those who weighed 70 kg, but there was a statistically significant increase in odds with increasing vertical location for those who weighed 90 kg (P = 0.01) (Figure 23).

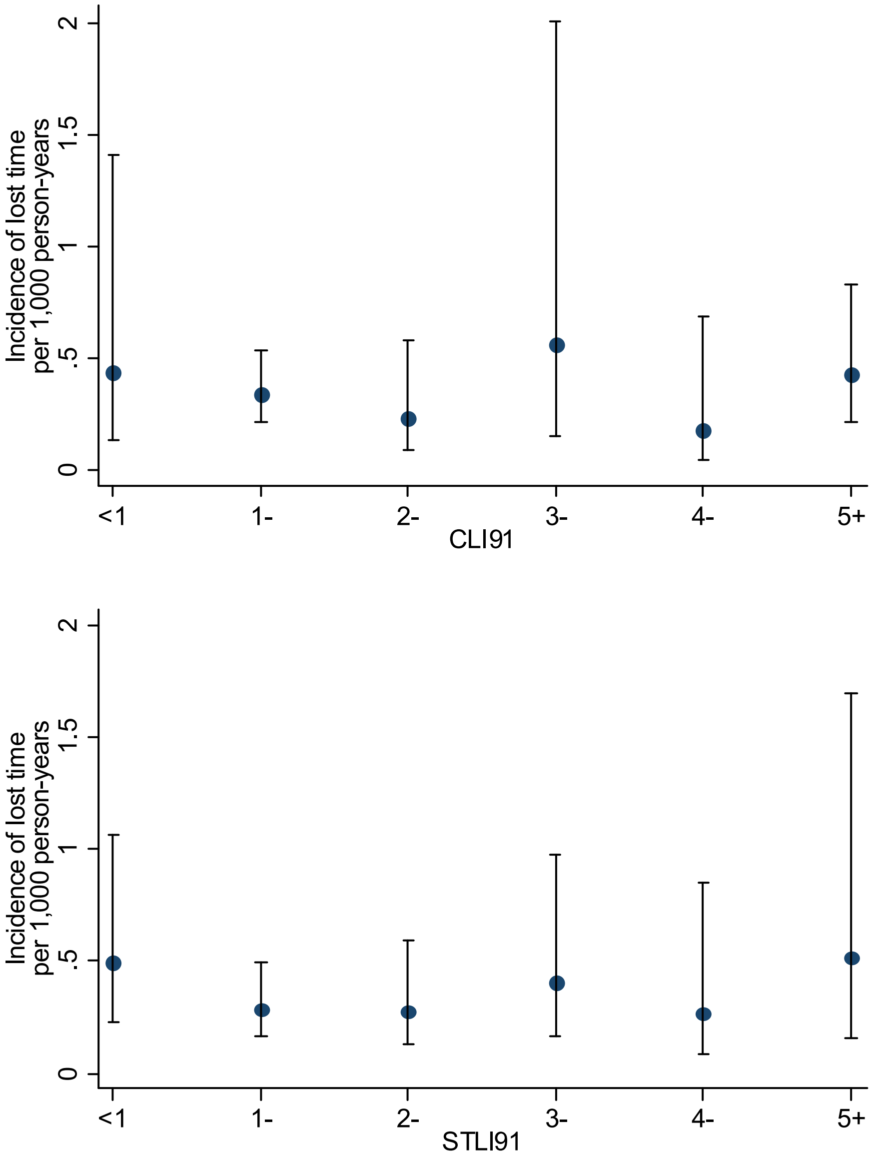


Figure 16 Incidence rate of lost time during the study period by CLI and STLI (Error bars represent 95% CIs)

Table 65 Distribution of CLI, STLI and task variables by LBP experience

	No LBP during previous 12 months	LBP during previous 12 months		P-value#	Total
		Work not affected	Lost time		
CLI	2.4 (1.5 – 4.7)	1.8 (1.4 – 4.7)	1.8 (1.2 – 8.7)	0.182	2.4 (1.4 – 4.7)
STLI	2.1 (1.4 – 3.5)	1.8 (1.1 – 3.5)	1.5 (1.1 – 3.5)	0.029*	2.1 (1.2 – 3.5)
Maximum load weight (kg)	14.8 (10.0 – 24.0)	12.0 (6.7 – 24.0)	12.5 (8.7 – 25.0)	0.081	12.5 (8.7 – 25.0)
Maximum horizontal location (cm)	50.1 (45.0 – 78.5)	59.4 (43.0 – 80.0)	62.5 (45.0 – 80.0)	0.488	58.6 (45.0 – 80.0)
Maximum vertical offset (cm) from 750 mm	45.0 (40.0 – 80.5)	56.6 (35.0 – 86.0)	57.5 (40.0 – 86.0)	0.498	46.2 (40.0 – 86.0)
Vertical travel distance (cm)	36.2 (25.0 – 60.7)	54.0 (25.0 – 65.0)	49.6 (25.0 – 54.0)	0.217	49.6 (25.0 – 64.0)
Maximum asymmetry angle (degrees)	0.0 (0.0 – 45.0)	0.0 (0.0 – 45.0)	0.0 (0.0 – 45.0)	0.884	0.0 (0.0 – 45.0)
Lifting frequency (lifts per min)	0.1 (0.0 – 0.5)	0.1 (0.0 – 0.8)	0.1 (0.0 – 0.5)	0.645	0.1 (0.0 – 0.6)

Data are medians with interquartile ranges in parentheses
#P-value for Kruskal-Wallis test

Table 66 Crude and adjusted ORs for lost time due to LBP by CLI and STLI, estimated using logistic regression

	Total number	Cases	Unadjusted OR (95% CI)	OR (95% CI) adjusted for weight, age, gender and previous LBP	OR (95% CI) adjusted for full model#
CLI					
< 1	25	3	1.0	1.0	1.0
1 +	227	36	1.4 (0.4 – 4.9)	1.4 (0.4 – 5.1)	1.9 (0.3 – 10.5)
< 3	172	25	1.0	1.0	1.0
3 +	80	14	1.2 (0.6 – 2.6)	1.2 (0.6 – 2.5)	1.7 (0.7 – 4.1)
Continuous model			1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)	1.1 (0.9 – 1.2)
STLI					
< 1	38	7	1.0	1.0	1.0
1 +	214	32	0.8 (0.3 – 1.9)	1.1 (0.4 – 2.9)	1.0 (0.3 – 3.4)
< 3	178	27	1.0	1.0	1.0
3 +	74	12	1.1 (0.5 – 2.3)	1.0 (0.4 – 2.1)	1.3 (0.5 – 3.2)
Continuous model			1.0 (0.8 – 1.2)	1.0 (0.9 – 1.3)	1.2 (0.9 – 1.5)

 # "Full model" refers to the model obtained from the personal variables

Table 67 Crude and adjusted HRs for lost time due to LBP by CLI and STLI, estimated using Cox regression

	Days at risk	*Cases*	*Unadjusted HR (95% CI)*	*HR (95% CI) adjusted for weight, age, gender and previous LBP*	*HR (95% CI) adjusted for full model[#]*
CLI					
< 1	16,637	6	1.0	1.0	1.0
1 +	132,313	44	0.8 (0.3 – 2.5)	0.7 (0.2 – 2.0)	0.9 (0.3 – 3.4)
< 3	98,683	32	1.0	1.0	1.0
3 +	47,267	18	1.2 (0.6 – 2.3)	1.2 (0.6 – 2.2)	1.2 (0.6 – 2.3)
Continuous model			1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)
STLI					
< 1	22,112	11	1.0	1.0	1.0
1 +	123,838	39	0.6 (0.3 – 1.5)	0.8 (0.4 – 1.7)	0.9 (0.3 – 2.2)
< 3	103,421	34	1.0	1.0	1.0
3 +	42,529	16	1.2 (0.6 – 2.3)	1.1 (0.6 – 2.1)	1.1 (0.5 – 2.1)
Continuous model			1.0 (0.8 – 1.3)	1.1 (0.9 – 1.3)	1.1 (0.9 – 1.4)

 # "Full model" refers to the model obtained from the personal variables

Table 68 Crude and adjusted ORs for reporting LBP by CLI and STLI, estimated using GEEs

	Follow-ups	*Cases*	*Unadjusted OR (95% CI)*	*OR (95% CI) adjusted for weight, age, gender and previous LBP*	*OR (95% CI) adjusted for full model[#]*
CLI					
< 1	118	35	1.0	1.0	1.0
1 +	1,063	257	0.7 (0.3 – 1.4)	0.8 (0.4 – 2.0)	0.9 (0.4 – 2.0)
< 3	806	217	1.0	1.0	1.0
3 +	375	75	0.7 (0.4 – 1.2)	0.7 (0.4 – 1.3)	1.1 (0.6 – 2.1)
Continuous model			0.9 (0.9 – 1.0)	1.0 (0.9 – 1.0)	1.0 (0.9 – 1.1)
STLI					
< 1	201	74	1.0	1.0	1.0
1 +	980	218	0.5 (0.2 – 0.8)*	0.6 (0.3 – 1.2)	0.6 (0.3 – 1.2)
< 3	842	225	1.0	1.0	1.0
3 +	339	67	0.7 (0.4 – 1.2)	0.7 (0.4 – 1.3)	1.1 (0.6 – 2.1)
Continuous model			0.8 (0.7 – 1.0)*	0.9 (0.7 – 1.0)	1.0 (0.8 – 1.2)

 # "Full model" refers to the model obtained from the personal variables

Table 69 Crude and adjusted ORs for lost time due to LBP by task variable, estimated using logistic regression

	Total number	*Cases*	*Unadjusted OR (95% CI)*	*OR (95% CI) adjusted for weight, age, gender and previous LBP*	*OR (95% CI) adjusted for full model*#
Maximum load weight (kg)					
< 10	78	12	1.0	1.0	1.0
10 –	88	15	1.1 (0.5 – 2.6)	1.6 (0.6 – 4.2)	1.7 (0.6 – 4.6)
20 +	86	12	0.9 (0.4 – 2.1)	1.1 (0.4 – 2.8)	1.2 (0.4 – 3.5)
Continuous model (per 10 kg)			0.9 (0.7 – 1.3)	1.0 (0.7 – 1.3)	1.0 (0.7 – 1.5)
Maximum horizontal location (cm)					
< 50	86	10	1.0	1.0	1.0
50 –	75	12	1.4 (0.6 – 3.6)	1.6 (0.6 – 4.5)	1.3 (0.4 – 4.4)
70 –	72	13	1.7 (0.7 – 4.1)	1.7 (0.6 – 4.6)	2.2 (0.7 – 6.7)
90 +	19	4	2.0 (0.6 – 7.3)	2.9 (0.6 – 13.6)	3.4 (0.7 – 17.3)
Continuous model (per 10 cm)			1.2 (1.0 – 1.4)	1.2 (1.0 – 1.5)	1.2 (1.0 – 1.5)
Maximum vertical offset (cm) from 750 mm					
< 40	55	6	1.0	1.0	1.0
40 –	90	12	1.3 (0.4 – 3.6)	1.2 (0.4 – 3.7)	1.0 (0.3 – 3.8)
60 –	32	5	1.5 (0.4 – 5.4)	1.6 (0.4 – 7.0)	1.8 (0.4 – 8.6)
80 +	75	16	2.2 (0.8 – 6.1)	1.9 (0.6 – 5.5)	1.9 (0.6 – 6.3)
Continuous model (per 10 cm)			1.1 (1.0 – 1.2)	1.1 (0.9 – 1.2)	1.1 (0.9– 1.3)
Vertical travel distance (cm)					
< 40	117	14	1.0	1.0	1.0
40 –	59	12	1.9 (0.8 – 4.4)	1.6 (0.6 – 4.1)	1.9 (0.6 – 5.8)
60 +	76	13	1.5 (0.7 – 3.4)	1.7 (0.6 – 4.3)	1.6 (0.5 – 4.7)
Continuous model (per 10 cm)			1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)
Maximum asymmetry angle (degrees)					
0	151	23	1.0	1.0	1.0
> 0	101	16	1.0 (0.5 – 2.1)	0.9 (0.4 – 1.9)	0.9 (0.4 – 2.2)
Continuous model (per 10°)			1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)
Lifting frequency (lifts per min)					
< 0.5	157	25	1.0	1.0	1.0
0.5 +	95	14	0.9 (0.4 – 1.9)	0.8 (0.4 – 1.6)	0.8 (0.3 – 1.8)
Continuous model			1.0 (0.7 – 1.3)	1.0 (0.7 – 1.4)	1.1 (0.8 – 1.5)
Coupling type					
Poor	216	35	1.0	1.0	1.0
Fair/Good	36	4	0.6 (0.2 – 1.9)	1.1 (0.3 – 3.3)	0.7 (0.2 – 2.3)

 # "Full model" refers to the model obtained from the personal variables

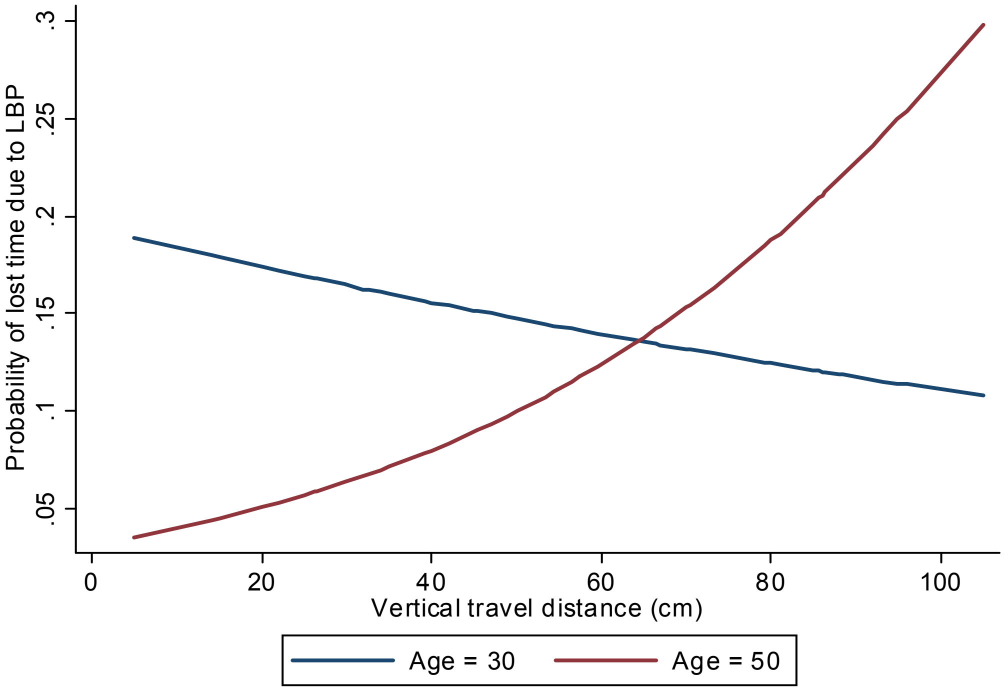


Figure 17 Effect of the interaction of age and vertical travel distance on the probability of lost time due to LBP. Estimated using logistic regression and shown for example ages of 30 and 50 years

Table 70 Crude and adjusted HRs for lost time due to LBP by task variable, estimated using Cox regression

	Days at risk	*Cases*	*Unadjusted HR (95% CI)*	*HR (95% CI) adjusted for weight, age, gender and previous LBP*	*HR (95% CI) adjusted for full model*[#]
Maximum load weight (kg)					
< 10	44,540	18	1.0	1.0	1.0
10 –	49,894	18	0.9 (0.4 – 2.0)	1.1 (0.5 – 2.5)	1.4 (0.6 – 3.3)
20 +	51,516	14	0.7 (0.3 – 1.6)	0.8 (0.4 – 1.9)	0.8 (0.4 – 2.0)
Continuous model (per 10 kg)			0.8 (0.6 – 1.2)	0.9 (0.6 – 1.2)	0.9 (0.7 – 1.3)
Maximum horizontal location (cm)					
< 50	50,368	10	1.0	1.0	1.0
50 –	44,347	14	1.6 (0.7 – 3.6)	1.8 (0.7 – 4.4)	1.3 (0.5 – 3.2)
70 –	40,736	20	2.5 (1.1 – 5.6)*	2.2 (1.0 – 5.1)	2.0 (0.9 – 4.5)
90 +	10,499	6	2.9 (0.9 – 9.1)	4.4 (1.2 – 16.9)*	3.7 (1.1 – 12.3)*
Continuous model (per 10 cm)			1.2 (1.1 – 1.4)**	1.3 (1.1 – 1.5)*	1.2 (1.0 – 1.5)*
Maximum vertical offset (cm) from 750 mm					
< 40	31,887	6	1.0	1.0	1.0
40 –	52,849	13	1.3 (0.5 – 3.4)	1.3 (0.5 – 3.3)	1.0 (0.3 – 3.1)
60 –	16,425	7	2.3 (0.7 – 7.3)	2.4 (0.7 – 8.4)	2.4 (0.7 – 8.6)
80 +	44,789	24	2.9 (1.1 – 7.2)*	2.2 (0.8 – 5.7)	1.7 (0.6 – 5.2)
Continuous model (per 10 cm)			1.1 (1.0 – 1.3)*	1.1 (1.0 – 1.2)	1.1 (1.0 – 1.2)
Vertical travel distance (cm)					
< 40	67,573	16	1.0	1.0	1.0
40 –	37,897	16	1.8 (0.8 – 4.0)	1.4 (0.7 – 3.0)	1.2 (0.5 – 2.8)
60 +	40,480	18	1.9 (0.9 – 4.0)	1.9 (0.9 – 4.2)	1.7 (0.7 – 4.0)
Continuous model (per 10 cm)			1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)
Maximum asymmetry angle (degrees)					
0	87,944	30	1.0	1.0	1.0
>0	58,006	20	1.0 (0.5 – 1.9)	0.9 (0.5 – 1.7)	1.0 (0.5 – 1.9)
Continuous model (per 10°			1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)
Lifting frequency (lifts per min)					
< 0.5	93,445	29	1.0	1.0	1.0
0.5 +	52,505	21	1.3 (0.7 – 2.5)	1.1 (0.6 – 2.0)	1.0 (0.5 – 2.0)
Continuous model			1.1 (0.9 – 1.3)	1.1 (0.9 – 1.4)	1.2 (0.9 – 1.5)
Coupling type					
Poor	124,147	44	1.0	1.0	1.0
Fair/Good	21,803	6	1.3 (0.4 – 4.0)	0.9 (0.3 – 2.6)	0.7 (0.2 – 2.0)

 # “Full model” refers to the model obtained from the personal variables;

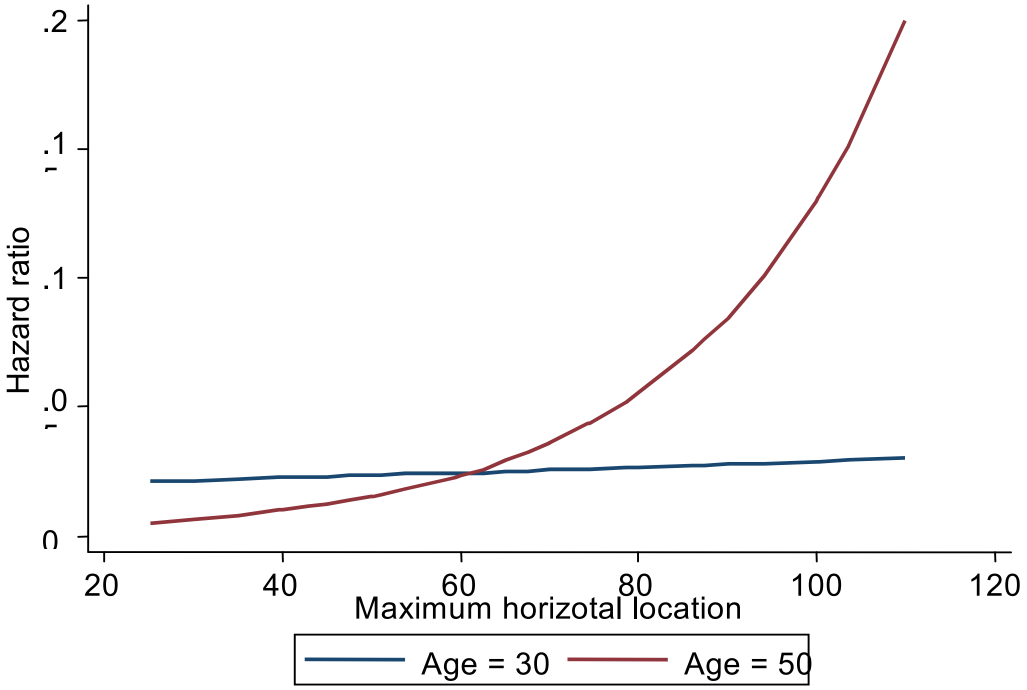


Figure 18 Effect of the interaction of age and horizontal location on the hazard of lost time due to LBP. Estimated using Cox regression and shown for example ages of 30 and 50 years

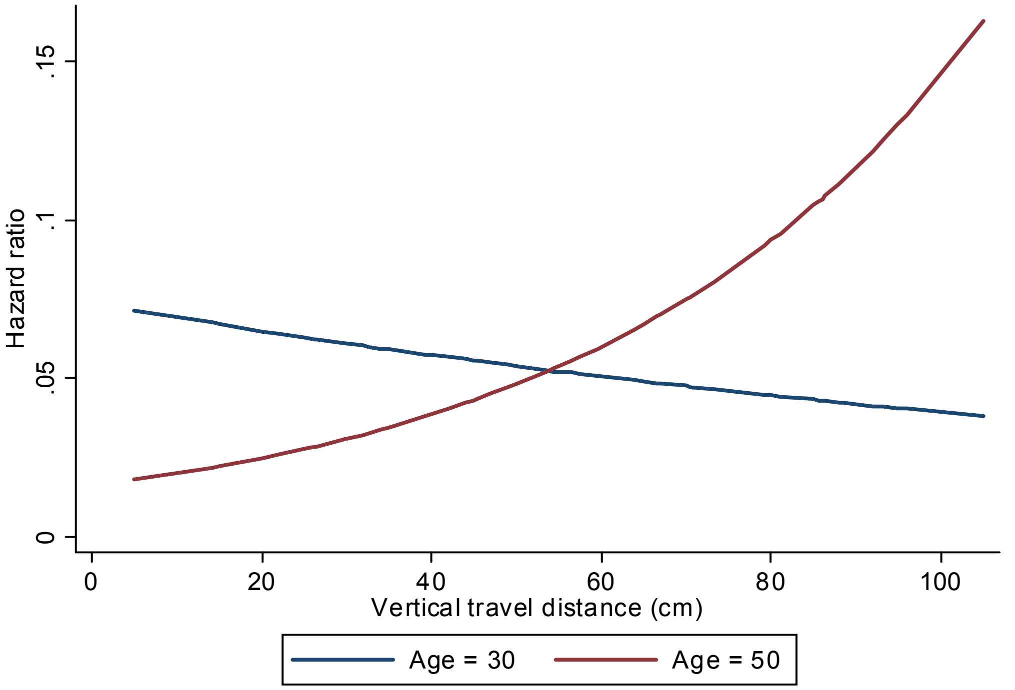


Figure 19 Effect of the interaction of age and vertical travel distance on the hazard of lost time due to LBP. Estimated using Cox regression and shown for example ages of 30 and 50 years

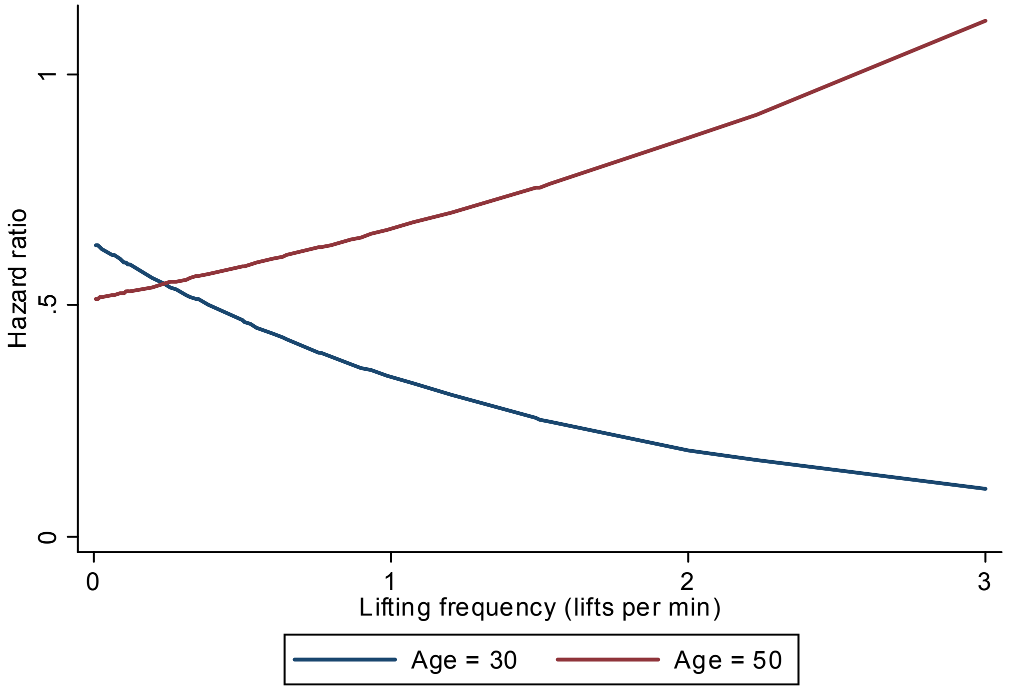


Figure 20 Effect of the interaction of age and lifting frequency on the hazard of lost time due to LBP. Estimated using Cox regression and shown for example ages of 30 and 50 years

Table 71 Crude and adjusted ORs for reporting LBP by task variable, estimated using GEEs

	Follow-ups	*Cases*	*Unadjusted OR (95% CI)*	*OR (95% CI) adjusted for weight, age, gender and previous LBP*	*OR (95% CI) adjusted for full model*[#]
Maximum load weight (kg)					
< 10	369	125	1.0	1.0	1.0
10 –	420	94	0.6 (0.3 – 1.1)	0.8 (0.4 – 1.5)	1.0 (0.5 – 2.0)
20 +	392	73	0.5 (0.3 – 0.9)*	0.6 (0.3 – 1.2)	0.9 (0.4 – 1.7)
Continuous model (per 10 kg)			0.8 (0.6 – 1.0)	0.8 (0.6 – 1.1)	0.9 (0.7 – 1.2)
Maximum horizontal location (cm)					
< 50	411	98	1.0	1.0	1.0
50 –	350	75	0.9 (0.5 – 1.7)	1.1 (0.6 – 2.2)	1.4 (0.6 – 3.0)
70 –	334	96	1.1 (0.6 – 2.1)	1.2 (0.6 – 2.2)	1.4 (0.7 – 3.1)
90 +	86	23	1.0 (0.4 – 2.8)	1.1 (0.3 – 4.4)	1.9 (0.5 – 6.4)
Continuous model (per 10 cm)			1.0 (0.9 – 1.2)	1.1 (0.9 – 1.2)	1.1 (1.0 – 1.3)
Maximum vertical offset (cm) from 750 mm)					
< 40	262	57	1.0	1.0	1.0
40 –	417	89	0.9 (0.5 – 0.7)	1.0 (0.5 – 2.1)	1.3 (0.6 – 2.9)
60 –	135	30	0.9 (0.3 – 2.4)	0.9 (0.3 – 2.9)	1.0 (0.3 – 3.1)
80 +	367	116	1.4 (0.7 – 2.9)	1.5 (0.7 – 2.9)	2.0 (0.8 – 4.6)
Continuous model (per 10 cm)			1.1 (1.0 – 1.2)	1.1 (1.0 – 1.2)	1.1 (1.0 – 1.2)
Vertical travel distance (cm)					
< 40	563	123	1.0	1.0	1.0
40 –	300	84	1.3 (0.7 – 2.4)	1.2 (0.6 – 2.3)	1.6 (0.7 – 3.7)
60 +	318	85	1.1 (0.6 – 2.0)	1.0 (0.5 – 1.9)	1.1 (0.6 – 2.1)
Continuous model (per 10 cm)			1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)
Maximum asymmetry angle (degrees)					
0	686	176	1.0	1.0	1.0
> 0	495	116	1.0 (0.6 – 1.6)	1.1 (0.6 – 1.8)	1.0 (0.6 – 1.8)
Continuous model (per 10°)			1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)	1.0 (0.9 – 1.1)
Lifting frequency (lifts per min)					
< 0.5	722	140	1.0	1.0	1.0
0.5 +	459	152	1.9 (1.1 – 3.1)*	1.5 (0.9 – 2.5)	1.4 (0.8 – 2.4)
Continuous model			1.0 (0.8 – 1.3)	1.1 (0.9 – 1.3)	1.1 (0.9 – 1.3)
Coupling type					
Poor	998	241	1.0	1.0	1.0
Fair/Good	183	51	1.2 (0.6 – 2.5)	2.1 (1.1 – 4.0)*	2.5 (1.3 – 4.9)**

 # "Full model" refers to the model obtained from the personal variables;

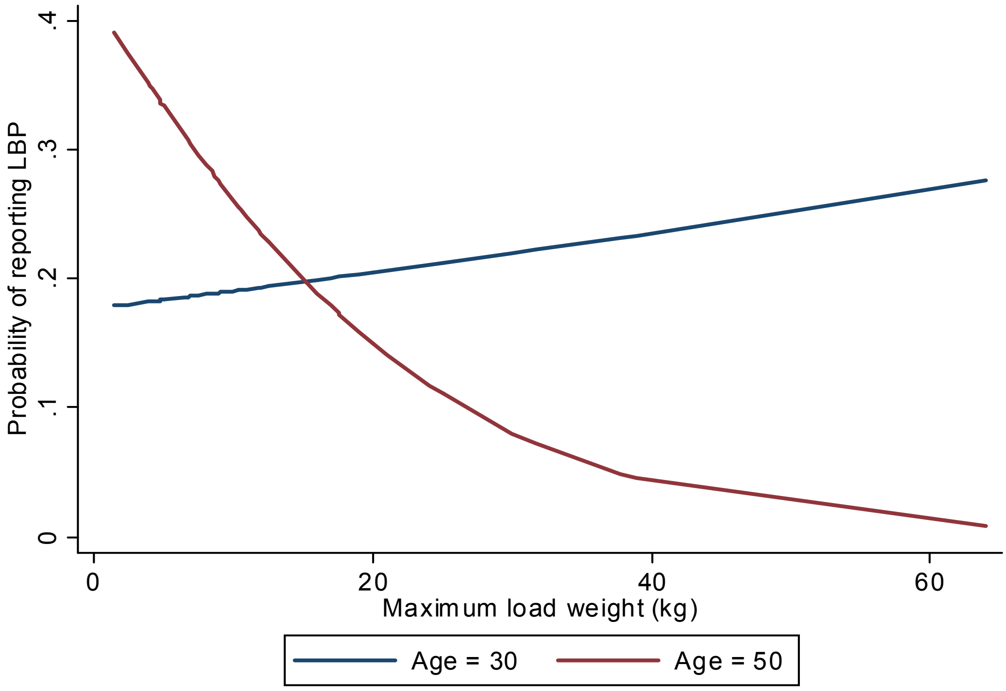


Figure 21 Effect of the interaction of age and load weight on the probability of reporting LBP during the study. Estimated using GEEs and shown for example ages of 30 and 50 years

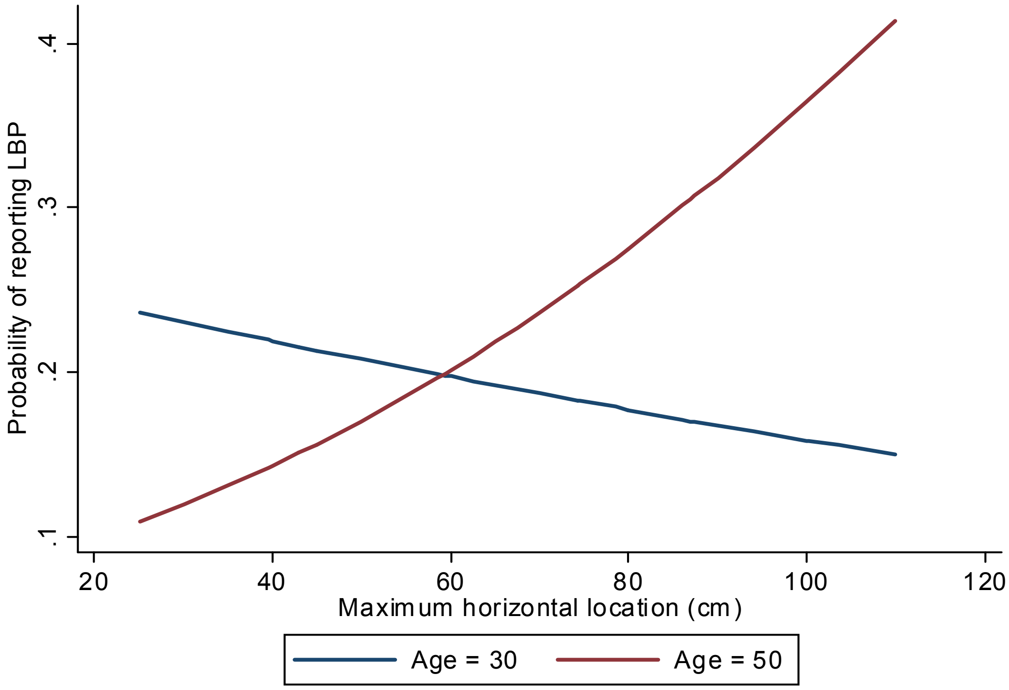


Figure 22 Effect of the interaction of age and horizontal location on the probability of reporting LBP during the study. Estimated using GEEs and shown for example ages of 30 and 50 years

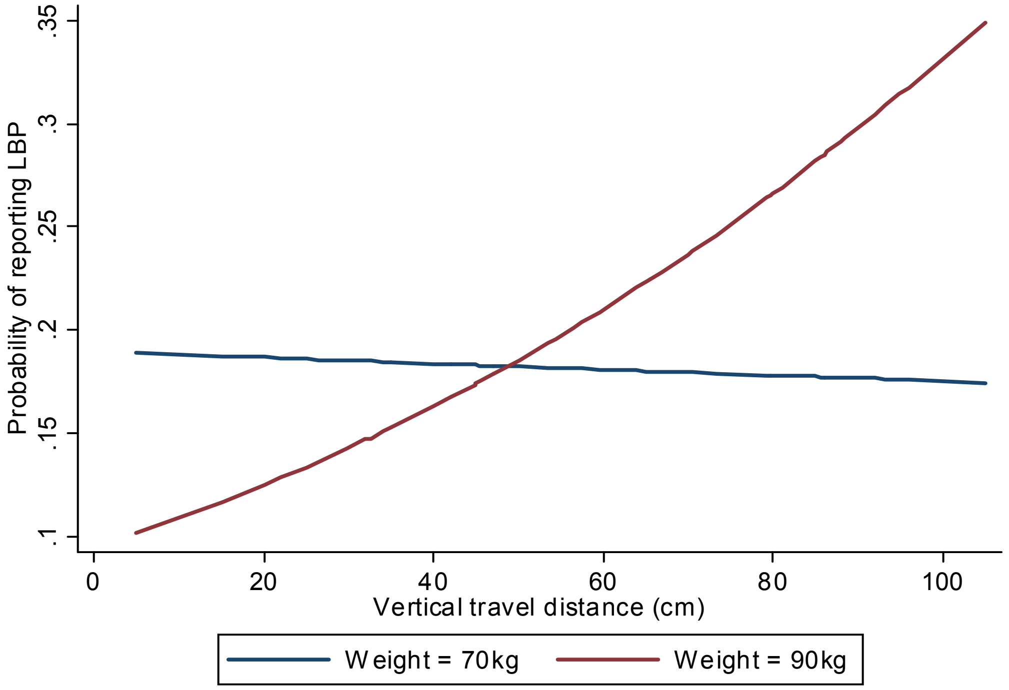


Figure 23 Effect of the interaction of weight and vertical travel distance on the probability of reporting LBP during the study. Estimated using GEEs and shown for example weights of 70 and 90 kg

9.9 ANY REPORT OF LBP

9.9.1 Logistic regression

LBP experience before the study was significantly associated with reporting LBP during the study period (Table 72). People that had suffered from LBP resulting in lost time before the study had nine time the odds of lost time during the study as people that had not experienced LBP before the study (OR = 9.1, 95% CI 4.4 – 18.6). Those who worked more than 40 hours a week had greater odds of reporting LBP (OR = 1.6, 95% CI 1.1 – 2.6). There was significant association between reporting of LBP and exercise, with those who exercise regularly having lower odds of reporting LBP (OR = 0.6, 95% CI 0.4 – 1.0) (Table 73). The significant interaction between exercise and gender (P = 0.0436) showed that males had reduced odds of reporting LBP if they exercised regularly (OR = 0.5, 95% CI 0.3 – 0.8), but a non-significant increase in odds was seen for females (OR = 1.6, 95% CI 0.6 – 4.3) (Table 74). A similar pattern was seen for regular aerobic exercise and gender.

Table 75 shows the crude and adjusted ORs associated with psychosocial variables. Supervisor climate, stimulus from the work, psychological work load and management commitment to health and safety all showed significant negative association with the probability of reporting LBP. However, after adjustment for age, gender and LBP experience these trends were no longer statistically significant. There was a significant interaction between LBP experience before the study and management commitment to health and safety (P = 0.0349). There was a significant decrease in the odds of reporting LBP with the Management commitment to health and safety score for those who had experienced LBP before the study without it affecting their work (Table 76, Figure 24). However, no significant trend was observed for those with other LBP experience.

Those who reported experiencing trouble with the neck and shoulders, and the lower body (hips/ thighs/ buttocks/ knees and ankles) were at greater odds of reporting LBP (neck and shoulders: OR = 1.6, 95% CI 1.0 – 2.5: lower body: OR = 2.1, 95% CI 1.3 – 3.3) (Table 77).

Those who experienced trouble with the lower back during the previous seven days and the previous three months were at greater odds of reporting LBP during the study (seven days: OR = 5.6, 95% CI 3.6 – 8.6; three months: OR = 6.2, 95% CI 3.6 – 10.6). There were no significant differences between those who reported that the lower back trouble prevented normal activities (Table 78).

The model that included if the person had experienced LBP during the previous 12 months had a lower AIC than using lower back trouble during the previous seven days or the previous three months (Table 79). Using LBP experience during the previous 12 months as a categorical variable (No; Yes, work not affected; Yes, lost time) did not improve the model fit.

The final logistic model using the baseline variables for reporting of LBP during the study period included age, gender, LBP experience in the 12 months leading up to the study, if the participant regularly did aerobic exercise and if they had trouble with the lower body during the previous three months. None of the interactions was significant in the final model. The Hosmer-Lemeshow goodness-of-fit statistic indicated that this was a reasonable model (P = 0.8941) (Table 80).

Table 72 Crude and adjusted ORs for reporting LBP by personal variables, estimated using logistic regression

	Total number	*Cases*	*OR (95% CI)*	*OR[#] (95% CI)*
LBP during previous 12 months				
No	222	68	1.0	
Yes: work not affected	131	93	5.5 (3.5 – 8.9)**	
Yes: lost time	55	44	9.1 (4.4 – 18.6)**	
P-value for continuous model			< 0.0001**	
Gender				
Male	332	165	1.0	
Female	76	40	1.1 (0.7 – 1.9)	
Age (years)				
< 30	74	34	1.0	
30 –	149	74	1.2 (0.7 – 2.0)	
40 +	184	97	1.3 (0.8 – 2.3)	
P-value for continuous model			0.358	
Weight (kg)				
< 70	104	49	1.0	1.0
70 –	105	53	1.1 (0.7 – 2.0)	1.2 (0.6 – 2.2)
80 –	102	50	1.1 (0.6 – 1.9)	1.2 (0.6 – 2.2)
90 +	87	48	1.4 (0.8 – 2.4)	1.5 (0.8 – 3.0)
P-value for continuous model			0.163	0.109
Height (m)				
< 1.70	103	48	1.0	1.0
1.70 –	84	51	1.8 (1.0 – 3.2)	2.3 (1.1 – 4.8)*
1.75 –	95	41	0.9 (0.5 – 1.5)	1.0 (0.5 – 2.1)
1.80 –	76	40	1.3 (0.7 – 2.3)	1.9 (0.8 – 4.1)
1.80 +	46	23	1.1 (0.6 – 2.3)	1.7 (0.7 – 4.2)
P-value for continuous model			0.549	0.223
BMI (kg/m^2)				
Normal (18.5 – 24.9)	152	70	1.0	1.0
Overweight (25.0 – 29.9)	175	96	1.4 (0.9 – 2.2)	1.4 (0.9 – 2.4)
Obese (30 +)	67	32	1.1 (0.6 – 1.9)	1.2 (0.6 – 2.3)
P-value for continuous model			0.135	0.188
Weekly working hours				
< 40	182	80	1.0	1.0
40 +	226	125	1.6 (1.1 – 2.3)*	1.6 (1.1 – 2.6)*
P-value for continuous model			0.222	0.345
Length of employment (years)				
< 1	42	16	1.0	1.0
1 –	147	67	1.4 (0.7 – 2.7)	1.3 (0.6 – 2.7)
5 –	79	46	2.3 (1.1 – 4.9)*	1.5 (0.6 – 3.5)
10 +	136	73	1.9 (0.9 – 3.8)	1.6 (0.7 – 3.7)

	Total number	***Cases***	***OR (95% CI)***	***OR$^{\#}$ (95% CI)***
P-value for continuous model			0.037*	0.099
Daily Travel time (min.)				
0	40	15	1.0	1.0
1 –	173	88	1.7 (0.9 – 3.5)	1.7 (0.8 – 3.8)
30 –	126	66	1.8 (0.9 – 3.8)	1.6 (0.7 – 3.7)
60 +	69	36	1.8 (0.8 – 4.0)	1.9 (0.8 – 4.6)
P-value for continuous model			0.255	0.379

 # ORs adjusted for age, gender, and previous LBP

Table 73 Crude and adjusted ORs for reporting LBP by lifestyle factors, estimated using logistic regression

	Total number	***Cases***	***OR (95% CI)***	***Adjusted OR$^{\#}$ (95% CI)***
Exercise regularly				
No	163	90	1.0	1.0
Yes	245	115	0.7 (0.5 – 1.1)	0.6 (0.4 – 1.0)*
Regularly do aerobic exercise				
No	185	104	1.0	1.0
Yes	223	101	0.6 (0.4 – 1.0)*	0.6 (0.4 – 0.9)*
Regularly do non-aerobic exercise				
No	337	164	1.0	1.0
Yes	71	41	1.4 (0.9 – 2.4)	1.5 (0.8 – 2.6)
Current smoker				
No	245	120	1.0	1.0
Yes	163	85	1.1 (0.8 – 1.7)	1.1 (0.7 – 1.7)
Number of cigarettes smoked				
< 10	32	20	1.0	1.0
10 –	82	39	0.5 (0.2 – 1.3)	0.4 (0.2 – 1.0)
20 +	46	24	0.7 (0.3 – 1.6)	0.6 (0.2 – 1.6)
P-value for continuous model			0.739	0.886
Smoking duration				
< 20	85	41	1.0	1.0
20 +	64	39	1.7 (0.9 – 3.2)	1.7 (0.6 – 5.0)
P-value for continuous model			0.125	0.322

 # Adjusted for age, gender, and previous LBP

Table 74 ORs for reporting LBP for regular exercise by gender, estimated using logistic regression

	Total number	***Cases***	***Adjusted OR$^{\#}$ (95% CI)***
Exercise regularly (No; Yes)			
Male	332	165	0.5 (0.3 – 0.8)**
Female	76	40	1.6 (0.6 – 4.3)

ORs represent change in OR for LBP when comparing none to some regular exercise
 # Adjusted for age, and previous LBP

Table 75 Crude and adjusted ORs for reporting LBP by psychosocial variables, estimated using logistic regression

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR$^{\#}$ (95% CI)*
Influence on and control over work				
[-10, -5]	67	37	1.0	1.0
[-5, 0]	114	63	1.0 (0.5 – 1.8)	1.1 (0.6 – 2.2)
[0, 5]	144	67	0.7 (0.4 – 1.3)	0.8 (0.4 – 1.6)
[5, 10]	67	29	0.6 (0.3 – 1.2)	0.8 (0.4 – 1.8)
P-value for continuous model			0.102	0.503
Supervisor climate				
[-10, -5]	43	26	1.0	1.0
[-5, 0]	107	63	0.9 (0.5 – 1.9)	0.9 (0.4 – 1.9)
[0, 5]	145	69	0.6 (0.3 – 1.2)	0.6 (0.3 – 1.3)
[5, 10]	97	38	0.4 (0.2 – 0.9)*	0.5 (0.2 – 1.2)
P-value for continuous model			0.008**	0.101
Stimulus from the work itself				
[-10, -5]	68	40	1.0	1.0
[-5, 0]	107	58	0.8 (0.4 – 1.5)	1.1 (0.6 – 2.2)
[0, 5]	131	61	0.6 (0.3 – 1.1)	0.9 (0.5 – 1.8)
[5, 10]	89	37	0.5 (0.3 – 1.0)	1.0 (0.5 – 2.1)
P-value for continuous model			0.013*	0.523
Relations with fellow workers				
[-10, -5]	10	6	1.0	1.0
[-5, 0]	64	36	0.9 (0.2 – 3.3)	0.6 (0.1 – 2.7)
[0, 5]	140	70	0.7 (0.2 – 2.5)	0.6 (0.1 – 2.5)
[5, 10]	178	84	0.6 (0.2 – 2.2)	0.7 (0.2 – 3.0)
P-value for continuous model			0.203	0.773
Psychological work load				
[-10, -5]	37	26	1.0	1.0
[-5, 0]	113	55	0.4 (0.2 – 0.9)*	0.2 (0.1 – 0.6)**
[0, 5]	150	81	0.5 (0.2 – 1.1)	0.5 (0.2 – 1.1)
[5, 10]	92	34	0.2 (0.1 – 0.6)**	0.2 (0.1 – 0.6)**
P-value for continuous model			0.001**	0.056
Management commitment to health and safety				
[-10, -5]	32	18	1.0	1.0
[-5, 0]	85	49	1.1 (0.5 – 2.4)	1.1 (0.5 – 2.8)
[0, 5]	136	74	0.9 (0.4 – 2.0)	1.0 (0.4 – 2.5)
[5, 10]	139	55	0.5 (0.2 – 1.1)	0.8 (0.3 – 1.8)
P-value for continuous model			0.020*	0.417

 # Adjusted for age, gender, and previous LBP

Table 76 ORs for reporting LBP for management commitment to health and safety by previous LBP, estimated using logistic regression

	Total number	*Cases*	*Adjusted OR*$^{\#}$ *(95% CI)*
Management commitment to health and safety			
No LBP in previous 12 months	214	67	1.0 (1.0 – 1.1)
LBP in previous 12 months: work not affected	216	88	0.9 (0.8 – 1.0)*
LBP in previous 12 months: lost time	52	41	1.0 (0.9 – 1.1)

ORs represent change in OR for LBP per unit change in management commitment to health and safety
 # Adjusted for age, and gender

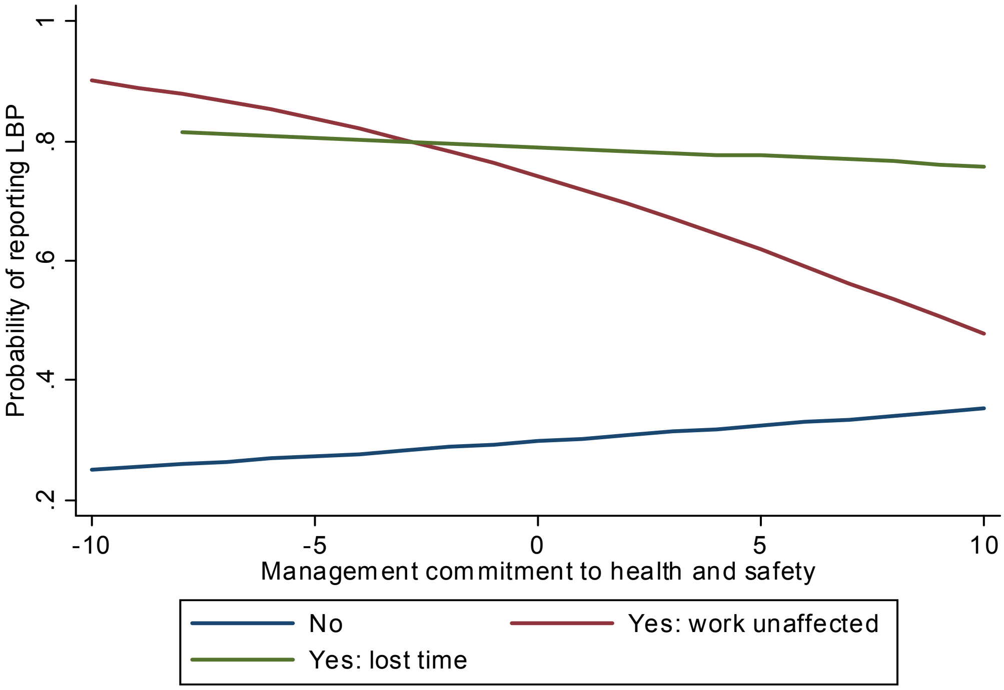


Figure 24 Probability of reporting LBP by management commitment to health and safety and previous LBP, estimated using logistic regression

Table 77 Crude and adjusted ORs for reporting LBP if trouble was experienced during the previous three months, estimated using logistic regression

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR*$^{\#}$ *(95% CI)*
Neck and shoulders				
No	224	91	1.0	1.0
Yes	176	109	2.4 (1.6 – 3.6)**	1.6 (1.0 – 2.5)*
Elbows and wrists/ hands				
No	244	104	1.0	1.0
Yes	158	96	2.1 (1.4 – 3.1)**	1.6 (1.0 – 2.5)
Upper back				
No	344	158	1.0	10
Yes	53	37	2.7 (1.5 – 5.1)**	1.7 (0.8 – 3.3)
Hips/ thighs/ buttocks, knees and ankles				
No	227	86	1.0	1.0
Yes	176	116	3.2 (2.1 – 4.8)**	2.1 (1.3 – 3.3)**

 # Adjusted for age, gender, and previous LBP

Table 78 Crude and adjusted ORs for reporting LBP by response to NMQ questions regarding the lower back, estimated using logistic regression

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR*$^{\#}$ *(95% CI)*
Lower back				
Trouble during previous seven days				
No	302	120	1.0	1.0
Yes	100	80	6.1 (3.5 – 10.4)**	5.6 (3.6 – 8.6)**
Trouble during previous three months				
No	219	59	1.0	1.0
Yes	188	135	5.5 (3.6 – 8.5)**	6.2 (3.6 – 10.6)**
Prevented normal activities				
No	126	86	1.0	1.0
Yes	58	45	1.6 (0.8 – 3.3)	1.6 (0.8 – 3.3)
Caused/made worse by job				
No	77	52	1.0	1.0
Yes	106	80	1.5 (0.8 – 2.8)	1.5 (0.8 – 2.8)

 # Adjusted for age and gender

Table 79 Statistics for models including different responses regarding previous LBP, estimated using logistic regression

Model	*Log likelihood*	*DF*	*AIC*
Age + gender +			
LBP during previous 12 months (No; Yes, work not affected; Yes, work affected)	-242.83	5	495.44
LBP during previous 12 months (No; Yes)	-243.53	4	495.07
Lower back trouble during previous three months (No; Yes)	-247.34	4	502.67
Lower back trouble during previous seven days (No; Yes)	-251.74	4	511.47

Table 80 Final personal variables model for reporting LBP using logistic regression

Variable	*Adjusted OR*# *(95% CI)*
Age at entry	1.00 (0.98 – 1.02)
Gender (male/ female)	1.02 (0.58 – 1.81)
LBP during previous 12 months	
No	1.00
Yes: work not affected	4.76 (2.90 – 7.82)**
Yes: lost time	7.58 (3.59 – 16.00)**
Regularly do aerobic exercise (No; Yes)	0.61 (0.39 – 0.95)*
Had trouble with lower body¶ during previous three months (No; Yes)	2.07 (1.31 – 3.26)**

Hosmer-Lemeshow goodness of fit statistic for model = 3.57, degrees of freedom=8, P = 0.8941

 # Adjusted for all variables listed

¶ Hips/ thighs/ buttocks, knees & ankles

9.9.2 GEEs

Altogether, 380 participants who completed 2,008 follow-up questionnaires were included in the analysis (Table 81). There were 476 reports of LBP by 168 participants during the study. At each follow-up, 91% of participants not reporting LBP did not report LBP at the next follow-up (Table 82). People that reported LBP had a 30% chance of not reporting LBP at the next follow-up. The QIC associated with the exchangeable correlation structure (the same correlation for all units) was the smallest and so was selected as the preferred structure (Table 83).

LBP experience before the study was significantly associated with reporting LBP during the study (Table 84). Participants that had lost time due to LBP before the study had eight times the odds of reporting LBP as compared to those with no LBP before the study (OR = 8.3, 95% CI 4.7 – 14.9). There was a statistically significant interaction between gender and weekly working hours (P = 0.0405; Table 85). For females, there was a statistically significant increase in odds of reporting LBP if they worked over 40 hours a week (OR = 3.0, 95% CI 1.2 – 8.0). This significant increase was not seen among males. There was also a statistically significant interaction between gender and age (P = 0.0021; Table 86, Figure 25). Those with greater ages were at lower odds of reporting LBP if they were female (OR = 0.94, 95% CI 0.90 – 0.98). However, for males, those at greater ages were at higher odds of reporting LBP, although this trend was not statistically significant (OR = 1.02, 95% CI 0.99 – 1.04).

There was significant association between reporting of LBP and exercise, with those who exercise regularly having lower odds of reporting LBP (OR = 0.6, 95% CI 0.4 – 0.9) (Table 87). The significant interaction between exercise and gender (P = 0.0376) showed that males had reduced odds of reporting LBP if they exercised regularly (OR = 0.5, 95% CI 0.3 – 0.7), but a non-significant increase in odds was seen for females that exercised regularly (OR = 1.5, 95% CI 0.6 – 3.9) (Table 88). A similar pattern was seen for regular aerobic exercise and gender (not shown).

Table 89 shows the crude and adjusted ORs associated with psychosocial variables. Supervisor climate, stimulus from the work, psychological workload, and management commitment to health and safety showed significant negative association with the probability of reporting LBP. After adjustment for age, gender and LBP experience, psychological workload remained statistically significant. There was a significant interaction between influence and control over work and LBP experience before the study (P = 0.0115; Table 90, Figure 26). Those with a more positive score for influence and control over work had greater odds of reporting LBP during the study if they had no previous LBP (OR = 1.07, 95% CI 1.00 – 1.14). However, those who had experienced LBP in the 12 months leading up to the study had lower odds of reporting LBP during the study the greater the score, although this decrease was not statistically significant. A similar pattern was seen for management commitment to health and safety and LBP experience (not shown).

Those who reported experiencing trouble with any body area in the three months leading up to the study were at greater odds of reporting LBP during the study (Table 91).

Those who experienced trouble with the lower back during the previous seven days and the previous three months were at greater odds of reporting LBP during the study (seven days: OR = 5.6, 95% CI 3.9 – 8.1; three months: OR = 5.6, 95% CI 3.8 – 8.1) (Table 92).

The model that included experience of LBP during the previous three months had a lower QIC_u than using lower back trouble during the previous seven days or the previous 12 months (Table 93). Using LBP experience during the previous 12 months as a categorical variable (No; Yes, work not affected; Yes, lost time) did not improve the model fit.

The final GEE model (Table 94) using the baseline variables for reporting of LBP during the study period included:

- If the participant regularly did aerobic exercise;
- If they had trouble with the arms during the previous three months;
- If they had trouble with the lower body during the previous three months;
- The gender and working hours interaction;
- The gender and age interaction;
- The LBP experience and Management commitment to health and safety interaction.

The goodness-of-fit statistic indicated that this was a reasonable model (P = 0.8674).

Table 81 Reporting of LBP at follow up

	Total	*Per subject*			
		mean	*min*	*median*	*max*
Number of subjects	515				
Did not complete six follow-ups due to dropout	135				
Subjects reporting LBP	168				
Reports of LBP	476	1.25	0	0	6
Number of follow-ups	2,008	5.28	1	6	6

Table 82 Transitions between not reporting and reporting LBP at the study follow-up

	No LBP reported	*Report LBP*	*Total*
No LBP reported	1,128 (91)	107 (9)	1,235 (100)
Report LBP	119 (30)	274 (70)	393 (100)
Total	1,247 (77)	381 (23)	1,628 (100)

Data are frequencies with row percentages in parenthesis
Rows reflect initial values and columns reflect values at the next follow-up

Table 83 Comparison of QIC values for several correlation structures for the GEE logistic model of reporting LBP

Correlation	*QIC*
Independent	1946.10
Exchangeable	1945.13
Unstructured	1946.07
Autoregressive of order 1	1954.72
Autoregressive of order 2	1955.10

Model used is age + gender + LBP experience 12 months before study

Table 84 Crude and adjusted ORs for reporting LBP by personal variables, estimated using GEEs.

	Follow-ups	*Cases*	*OR (95% CI)*	*Adjusted OR[#] (95% CI)*
LBP during previous 12 months				
No	1,142	115	1.0	
Yes: work not affected	613	242	6.1 (3.9 – 9.4)**	
Yes: lost time	253	119	8.3 (4.7 – 14.9)**	
P-value for continuous model			< 0.0001**	
Gender				
Male	1,612	403	1.0	
Female	396	73	0.8 (0.5 – 1.3)	
Age (years)				
< 30	317	73	1.0	
30 –	730	154	1.0 (0.6 – 1.7)	
40 +	955	249	1.2 (0.7 – 2.0)	
P-value for continuous model			0.491	
Weight (kg)				
< 70	504	98	1.0	1.0
70 –	503	140	1.5 (0.9 – 2.7)	1.4 (0.8 – 2.5)
80 –	499	115	1.2 (0.7 – 2.2)	1.2 (0.7 – 2.2)
90 +	449	119	1.5 (0.8 – 2.6)	1.4 (0.7 – 2.5)
P-value for continuous model			0.147	0.331
Height (m)				
< 1.70	543	104	1.0	1.0
1.70 –	394	140	2.1 (1.2 – 3.8)*	1.8 (0.9 – 3.7)
1.75 –	456	84	1.0 (0.5 – 1.7)	0.7 (0.4 – 1.5)
1.80 –	363	89	1.3 (0.7 – 2.3)	1.2 (0.6 – 2.5)
1.85 +	230	56	1.4 (0.7 – 2.7)	1.3 (0.6 – 2.8)
P-value for continuous model			0.336	0.774
BMI (kg/m^2)				
Normal (18.5 – 24.9)	752	459	1.0	1.0
Overweight (25.0 – 29.9)	841	234	1.4 (0.9 – 2.2)	1.4 (0.9 – 2.1)
Obese (30+)	340	77	1.1 (0.6 – 1.9)	1.3 (0.6 – 2.4)
P-value for continuous model			0.167	0.322
Weekly working hours				
< 40	941	198	1.0	1.0
40 +	1,067	278	1.3 (0.9 – 1.9)	1.2 (0.8 – 1.8)
P-value for continuous model			0.132	0.256
Length of employment (years)				
< 1	182	27	1.0	1.0
1 –	757	137	1.4 (0.6 – 3.1)	1.1 (0.5 – 2.4)
5 –	361	126	3.1 (1.3 – 7.2)**	1.8 (0.8 – 4.1)
10 +	684	177	2.0 (0.9 – 4.5)	1.5 (0.6 – 3.5)

	Follow-ups	*Cases*	*OR (95% CI)*	*Adjusted OR# (95% CI)*
P-value for continuous model			0.039*	0.119
Daily Travel time (min.)				
0	167	35	1.0	1.0
1 –	886	199	1.1 (0.5 – 2.1)	0.9 (0.5 – 1.8)
30 –	623	155	1.2 (0.6 – 2.5)	0.9 (0.5 – 1.9)
60 +	332	87	1.3 (0.6 – 2.8)	1.3 (0.6 – 2.7)
P-value for continuous model			0.481	0.567

 # Adjusted for age, gender, and previous LBP

Table 85 ORs for reporting LBP for weekly working hours by gender, estimated using GEEs

	Follow-ups	*Cases*	*Adjusted OR# (95% CI)*
Weekly working hours (<40/ 40 +)			
Male	1,612	403	1.0 (0.6 – 1.6)
Female	395	73	3.0 (1.2 – 8.0)*

ORs represent change in OR for LBP when comparing no regular aerobic exercise to regular aerobic exercise
 # Adjusted for age, and previous LBP

Table 86 ORs for reporting LBP for age at baseline by gender, estimated using GEEs

	Follow-ups	*Cases*	*Adjusted OR# (95% CI)*
Age at baseline (years)			
Male	1,606	403	1.02 (0.99 – 1.04)
Female	396	73	0.94 (0.90 – 0.98)**

ORs represent change in OR for LBP per unit change in age
 # Adjusted for age, and previous LBP

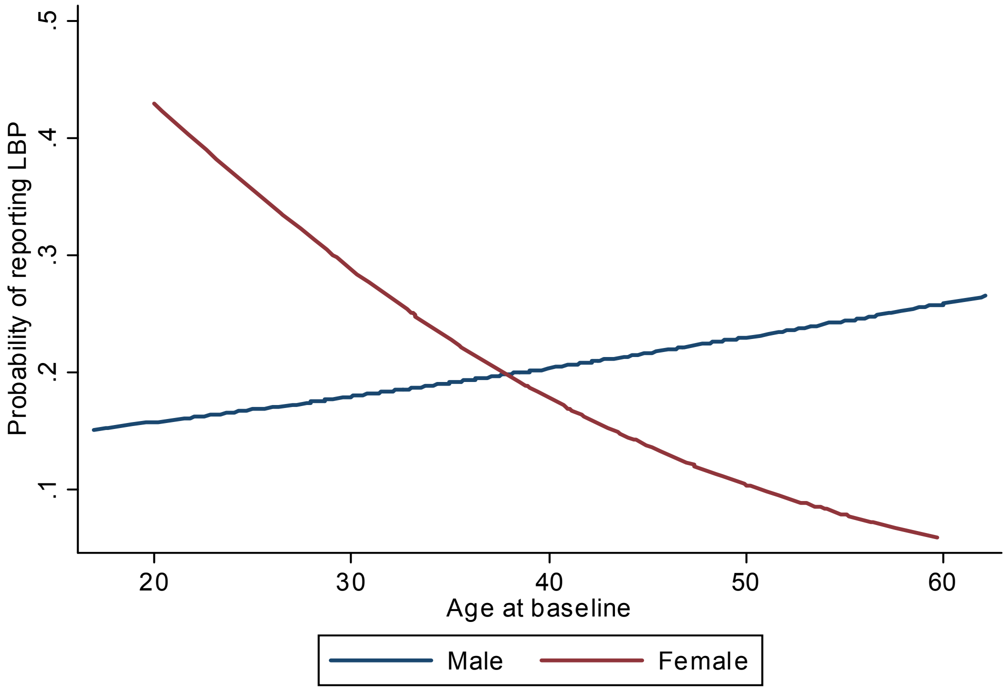


Figure 25 Probability of reporting LBP by age and gender, estimated using GEEs

Table 87 Crude and adjusted ORs for reporting LBP by lifestyle factors, estimated using GEEs

	Follow-ups	*Cases*	*OR (95% CI)*	*Adjusted OR# (95% CI)*
Exercise regularly				
No	827	227	1.0	1.0
Yes	1,181	249	0.7 (0.5 – 1.0)	0.6 (0.4 – 0.9)**
Regularly do aerobic exercise				
No	932	268	1.0	1.0
Yes	1,076	208	0.6 (0.4 – 0.9)**	0.5 (0.3 – 0.8)**
Regularly do non-aerobic exercise				
No	1,701	392	1.0	1.0
Yes	307	84	1.3 (0.8 – 2.2)	1.2 (0.7 – 2.1)
Current smoker				
No	1,228	278	1.0	1.0
Yes	780	198	1.2 (0.8 – 1.8)	1.1 (0.7 – 1.7)
Number of cigarettes smoked				
< 10	150	43	1.0	1.0
10 –	384	75	0.6 (0.3 – 1.3)	0.4 (0.2 – 1.1)
20 +	236	75	1.2 (0.5 – 2.8)	1.1 (0.5 – 2.8)
P-value for continuous model			0.263	0.406
Smoking duration				
< 20	396	82	1.0	1.0
20 +	325	107	1.8 (1.0 – 3.3)	2.5 (0.9 – 6.7)
P-value for continuous model			0.068	0.068

 # Adjusted for age, gender, and previous LBP

Table 88 ORs for reporting LBP for regular exercise by gender, estimated using GEEs

	Follow-ups	*Cases*	*Adjusted OR# (95% CI)*
Exercise regularly (No; Yes)			
Male	1,612	403	0.5 (0.3 – 0.7)**
Female	396	73	1.5 (0.6 – 3.9)

ORs represent change in OR for LBP when comparing no regular exercise to regular exercise
 # Adjusted for age, and gender

Table 89 Crude and adjusted ORs for reporting LBP by psychosocial variables, estimated using GEEs

	Follow-ups	*Cases*	*OR (95% CI)*	*Adjusted OR$^{\#}$ (95% CI)*
Influence on and control over work				
[-10, -5]	302	86	1.0	1.0
[-5, 0]	561	136	0.8 (0.4 – 1.5)	0.7 (0.4 – 1.3)
[0, 5]	737	181	0.8 (0.4 – 1.4)	0.8 (0.4 – 1.5)
[5, 10]	329	64	0.5 (0.3 – 1.1)	0.6 (0.3 – 1.4)
P-value for continuous model			0.120	0.436
Supervisor climate				
[-10, -5]	207	52	1.0	1.0
[-5, 0]	476	152	1.3 (0.6 – 2.8)	1.3 (0.6 – 2.6)
[0, 5]	737	162	0.8 (0.4 – 1.7)	0.9 (0.4 – 1.8)
[5, 10]	509	101	0.7 (0.3 – 1.5)	0.9 (0.4 – 1.9)
P-value for continuous model			0.045*	0.351
Stimulus from the work itself				
[-10, -5]	294	79	1.0	1.0
[-5, 0]	561	155	1.0 (0.6 – 1.8)	1.3 (0.7 – 2.5)
[0, 5]	643	156	0.8 (0.4 – 1.4)	1.2 (0.6 – 2.1)
[5, 10]	431	77	0.5 (0.3 – 1.0)*	1.0 (0.5 – 2.0)
P-value for continuous model			0.019*	0.521
Relations with fellow workers				
[-10, -5]	54	21	1.0	1.0
[-5, 0]	287	78	0.6 (0.2 – 2.3)	0.5 (0.2 – 1.5)
[0, 5]	681	175	0.5 (0.1 – 1.9)	0.5 (0.2 – 1.5)
[5, 10]	907	193	0.4 (0.1 – 0.5)	0.6 (0.2 – 1.6)
P-value for continuous model			0.075	0.890
Psychological work load				
[-10, -5]	194	66	1.0	1.0
[-5, 0]	510	147	0.7 (0.4 – 1.4)	0.5 (0.3 – 1.1)
[0, 5]	768	200	0.6 (0.3 – 1.2)	0.7 (0.4 – 1.2)
[5, 10]	457	54	0.3 (0.1 – 0.6)**	0.3 (0.1 – 0.7)**
P-value for continuous model			< 0.0001**	0.016*
Management commitment to health and safety				
[-10, -5]	130	28	1.0	1.0
[-5, 0]	404	125	1.6 (0.6 – 3.9)	1.9 (0.8 – 4.4)
[0, 5]	675	192	1.5 (0.6 – 3.5)	1.8 (0.8 – 4.0)
[5, 10]	720	122	0.7 (0.3 – 1.7)	1.3 (0.6 – 2.8)
P-value for continuous model			0.017*	0.448

 # Adjusted for age, gender, and previous LBP

Table 90 ORs for reporting LBP for influence and control over work by previous LBP, estimated using GEEs

	Follow-ups	*Cases*	*Adjusted OR# (95% CI)*
Influence and control over work			
No LBP in previous 12 months	1,093	114	1.07 (1.00 – 1.14)*
LBP before study: work not affected	600	239	0.93 (0.86 – 1.00)
LBP before study: lost time	236	114	0.94 (0.85 – 1.04)

ORs represent change in OR for LBP per unit change in influence and control over work
 # Adjusted for age, gender and previous LBP

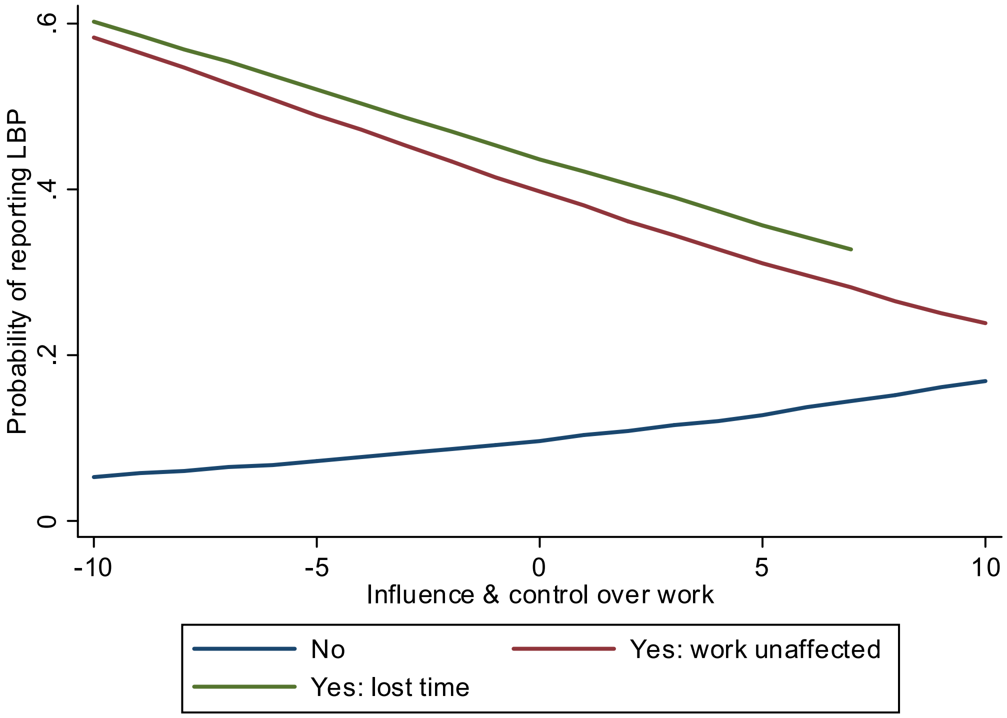


Figure 26 Probability of reporting LBP by influence and control over work and previous LBP, estimated using GEEs

Table 91 Crude and adjusted ORs for reporting LBP if trouble was experienced during the previous three months, estimated using GEEs

	Follow-ups	*Cases*	*OR (95% CI)*	*Adjusted OR*# *(95% CI)*
Neck and shoulders				
No	1,146	186	1.0	1.0
Yes	823	280	2.6 (1.8 – 3.9)**	1.7 (1.1 – 2.6)*
Elbows and wrists/ hands				
No	1,226	197	1.0	1.0
Yes	763	271	2.9 (2.0 – 4.3)**	2.3 (1.5 – 3.4)**
Upper back				
No	1,740	361	1.0	1.0
Yes	237	99	2.7 (1.6 – 4.6)**	6.5 (4.2 – 9.8)**
Hips/ thighs/ buttocks, knees & ankles				
No	1,153	175	1.0	1.0
Yes	834	296	3.0 (2.0 – 4.4)**	1.9 (1.3 – 2.9)**

 # Adjusted for age, gender, and previous LBP

Table 92 Crude and adjusted ORs for reporting LBP by response to NMQ questions regarding the lower back, estimated using GEEs

	Follow-ups	*Cases*	*OR (95% CI)*	*Adjusted OR*# *(95% CI)*
Lower back				
Trouble during previous seven days				
No	1,514	229	1.0	1.0
Yes	479	244	5.6 (3.7 – 8.4)**	5.5 (3.6 – 8.4)**
Trouble during previous three months				
No	1,107	105	1.0	1.0
Yes	901	371	6.5 (4.3 – 9.9)**	6.5 (4.2 – 9.8)**
Prevented normal activities				
No	650	252	1.0	1.0
Yes	237	108	1.3 (0.7 – 2.2)	1.2 (0.7 – 2.1)
Caused/made worse by job				
No	380	135	1.0	1.0
Yes	506	234	1.6 (1.0 – 2.6)	1.6 (1.0 – 2.6)

 # Adjusted for age and gender

Table 93 Comparison of QIC_u values for GEE models of reporting LBP

Model	*QIC_u*
Age + gender +	
LBP during previous 12 months (No; Yes, work not affected; Yes, work affected)	1923.96
LBP during previous 12 months (No; Yes)	1918.68
Lower back trouble during previous three months (No; Yes)	1952.01
Lower back trouble during previous days (No; Yes)	1922.37

Table 94 Final GEEs personal variables model for reporting LBP

Variable	***Adjusted OR[#] (95% CI)***
Regular aerobic exercise (No; Yes)	0.45 (0.29 – 0.69)**
Trouble with arms[†] during previous three months (No; Yes)	2.23 (1.45 – 3.43)**
Trouble with lower body[¶] during previous three months (No; Yes)	1.54 (0.99 – 2.39)
Gender and weekly working hours (<40/ 40 +) interaction:	
Male	0.86 (0.54 – 1.37)
Female	3.87 (1.32 – 11.35)*
Gender and age at baseline interaction:	
Male	1.01 (0.99 – 1.04)
Female	0.92 (0.87 – 0.98)*
LBP experience and Management commitment to health and safety interaction:	
LBP during previous 12 months (mean psychosocial score)	
No	1.00
Yes: work not affected	7.01 (3.88 – 12.64)**
Yes: lost time	13.52 (6.47 – 28.26)**
Psychosocial score	
No LBP in previous 12 months	1.10 (1.02 – 1.19)*
LBP in previous 12 months: work not affected	0.97 (0.90 – 1.04)
LBP in previous 12 months: lost time	0.93 (0.85 – 1.02)

$\chi 2$ goodness of fit statistic for model =4.60, degrees of freedom=9, P = 0.8674

 # Adjusted for all variables listed

† Elbows and wrists/ hands

¶ Hips/ thighs/ buttocks, knees & ankles

10 RISK OF LOST TIME DUE TO OTHER INJURY

10.1 METHODS

The same methods (logistic regression, Cox regression and AFT models) were used to investigate lost time due to injury other than LBP as had been used to investigate lost time due to LBP. Only statistically significant results and the final models are presented.

10.2 RESULTS

10.2.1 Descriptive statistics

Figure 27 indicates the types of the 113 non-LBP injuries reported by 94 subjects. Only 60 of these (53%) resulted in time off work. Approximately one-third reported injuries to other parts of the musculoskeletal system.

Figure 28 indicates how the "other" MSD incident cases were distributed across the body. Six individuals reported hernias. The "other trunk" category includes injuries to the upper back or side of the trunk. Shoulder or neck injuries are included in the "Upper limb" category.

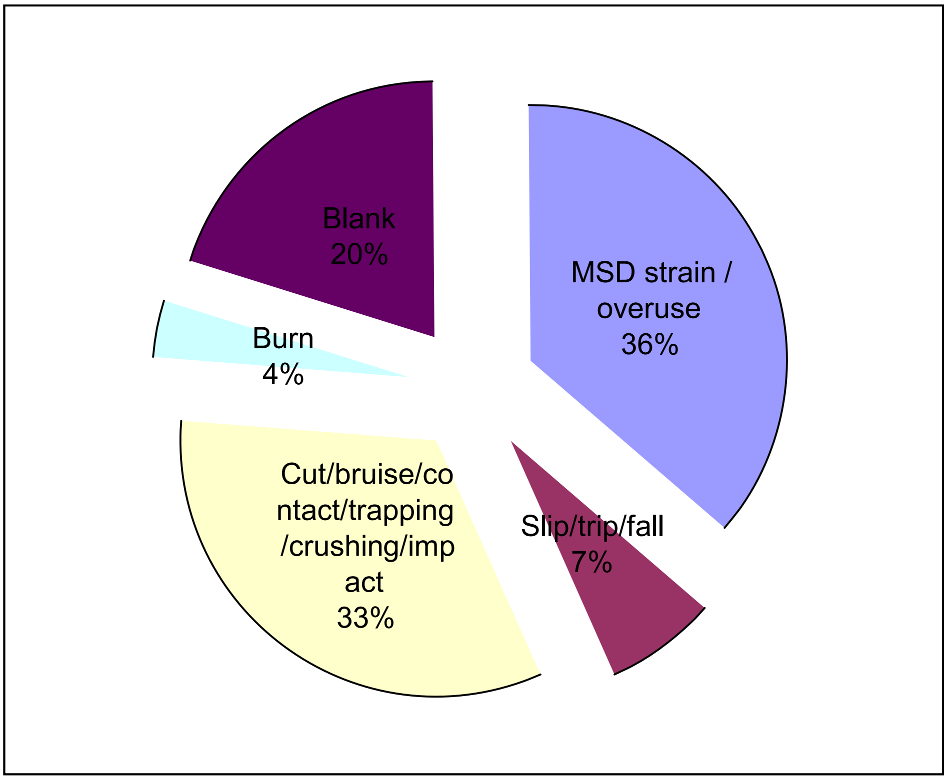


Figure 27 Breakdown of reports of all non-LBP injuries at work

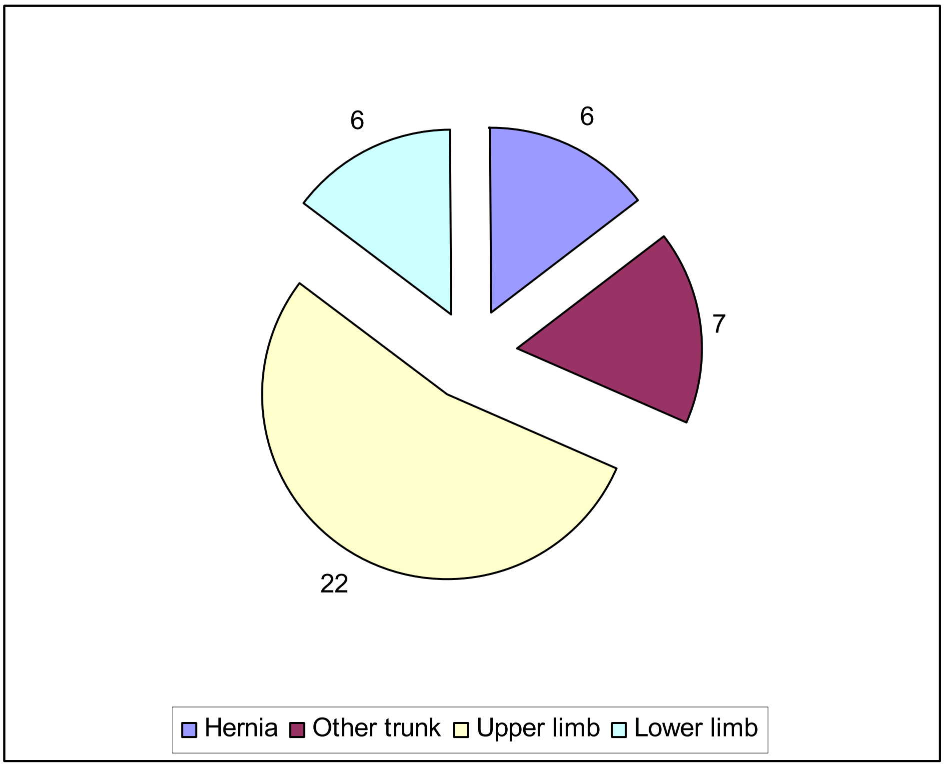


Figure 28 Breakdown of reports of MSD strain/overuse injuries

10.2.2 Logistic regression

55 participants reported losing time due to injuries other than LBP during the study period (Table 95). Of the 515 recruited at baseline, 129 were not included in the analysis due to dropout and not reporting lost time due to injury.

Table 95 Reporting of lost time due to injury other than LBP by dropout status

	Dropout	*Non dropout*	*Total*
Lost time due to injury	22	33	55
No lost time reported	129#	331	
Total	151	364	515

 # Excluded from logistic regression analysis

LBP experience was significantly associated with lost time due to injury other than LBP (Table 96). People that had suffered from LBP resulting in lost time before the study had about four times the odds of losing time due to other injuries during the study (OR = 4.2, 95% CI 2.0 – 8.7). This was about half the value found when lost time due to LBP was the outcome of interest (OR = 8.6, 95% CI 4.1 – 18.3). Increasing age was associated with increased odds of lost time due to injury, with those aged over 40 years having five times the odds compared to those aged less than 30 years (OR = 5.2, 95% CI 1.6 – 17.7). Note that age was not a significant variable when lost time due to LBP was investigated. After adjustment for age, gender and LBP experience, length of employment, and daily travel time to and from work in a vehicle, were significantly associated with lost time due to injury. Again, these were not found to be significant for LBP. An increase in the length of employment was associated with a decrease in the odds of lost time due to injury (P = 0.003), but an increase in daily travel time was associated with increased odds of lost time due to injury (P = 0.033).

As with lost time due to LBP, there were no significant lifestyle factors for lost time due to injury but four of the six psychosocial variables were significantly associated with it (Table 96) compared to just one (supervisor climate) for lost time due to LBP. All the significant variables showed decreasing odds of lost time due to injury with increasing (more positive) psychosocial score. Experiencing trouble with the neck and shoulders, and elbows and wrists/ hands approximately doubled the odds of losing work time due to injury during the study period (neck and shoulders: OR = 2.1, 95% CI 1.1 – 3.9; elbows and wrists/ hands: OR = 1.9, 95% CI 1.0 – 3.5). Again, no significant associations were found here when lost time due to LBP was investigated.

The final logistic models for lost time due to LBP (Table 46) and due to other injuries (Table 97) were not identical. Both included Age and Gender. The ‘other injury’ model additionally included Length of employment and the Management commitment to health and safety psychosocial variable as protective factors and an interaction between experience of LBP in the previous 12 months and the Supervisor climate psychosocial variable. In the LBP model there was an interaction between LBP experience and BMI, but Supervisor climate was protective, independent of LBP experience.

Table 96 Crude and adjusted ORs for lost time due to injury other than LBP , estimated using logistic regression

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR*$^{\#}$ *(95% CI)*
Personal variables				
LBP during previous 12 months				
No	217	22	1.0	
Yes: work not affected	116	16	1.4 (0.7 – 2.8)	
Yes: lost time	53	17	4.2 (2.0 – 8.7)**	
P-value for continuous model			< 0.0001**	
Gender				
Male	315	42	1.0	
Female	71	13	1.5 (0.7 – 2.9)	
Age (years)				
< 30	70	3	1.0	
30 –	136	18	3.4 (1.0 – 12.0)	
40 +	179	34	5.2 (1.6 – 17.7)**	
P-value for continuous model			0.021*	
Length of employment (years)				
< 1	10	44	1.0	1.0
1 –	20	140	0.6 (0.2 – 1.3)	0.5 (0.2 – 1.2)
5 –	10	73	0.5 (0.2 – 1.4)	0.4 (0.1 – 1.1)
10 +	14	125	0.4 (0.2 – 1.1)	0.2 (0.1 – 0.5)**
P-value for continuous model			0.137	0.003**
Daily travel time (min.)				
0	39	2	1.0	1.0
1 –	164	15	1.9 (0.4 – 8.5)	1.6 (0.3 – 7.5)
30 –	115	22	4.4 (1.0 – 19.6)	3.5 (0.7 – 16.1)
60 +	68	16	5.7 (1.2 – 26.3)*	4.5 (0.9 – 21.6)
P-value for continuous model			0.018*	0.033*
Psychosocial variables				
Influence and control over work				
[-10, -5]	62	15	1.0	1.0
[-5, 0]	106	19	0.7 (0.3 – 1.5)	0.9 (0.4 – 2.1)
[0, 5]	138	12	0.3 (0.1 – 0.7)**	0.4 (0.2 – 1.1)
[5, 10]	64	4	0.2 (0.1 – 0.7)**	0.3 (0.1 – 1.1)
P-value for continuous model			< 0.0001**	0.009**
Supervisor climate				
[-10, -5]	38	12	1.0	1.0
[-5, 0]	97	15	0.4 (0.2 – 1.0)*	0.4 (0.2 – 1.1)
[0, 5]	139	16	0.3 (0.1 – 0.7)**	0.3 (0.1 – 0.8)*
[5, 10]	96	7	0.2 (0.1 – 0.5)**	0.2 (0.1 – 0.7)**
P-value for continuous model			< 0.0001**	0.003**

	Total number	*Cases*	*OR (95% CI)*	*Adjusted OR$^{\#}$ (95% CI)*
Psychological work load				
[-10, -5]	33	7	1.0	1.0
[-5, 0]	104	18	0.8 (0.3 – 2.1)	0.7 (0.3 – 2.1)
[0, 5]	145	18	0.5 (0.2 – 1.4)	0.5 (0.2 – 1.5)
[5, 10]	88	7	0.3 (0.1 – 1.0)*	0.3 (0.1 – 1.1)
P-value for continuous model			0.006**	0.019*
Management commitment to health and safety				
[-10, -5]	28	11	1.0	1.0
[-5, 0]	78	13	0.3 (0.1 – 0.8)*	0.3 (0.1 – 0.9)*
[0, 5]	130	17	0.2 (0.1 – 0.6)**	0.3 (0.1 – 0.7)*
[5, 10]	134	9	0.1 (0.04 – 0.3)**	0.1 (0.05 – 0.4)**
P-value for continuous model			< 0.0001**	0.002**
NMQ				
Trouble during previous three months				
Neck and shoulders				
No	214	20	1.0	1.0
Yes	164	34	2.5 (1.4 – 4.6)**	2.1 (1.1 – 3.9)*
Elbows and wrists/ hands				
No	234	25	1.0	1.0
Yes	147	29	2.1 (1.1 – 3.7)*	1.9 (1.0 – 3.5)*

 # Adjusted for age, gender, and previous LBP

Table 97 Final personal variables model for lost time from injury other than LBP , estimated using logistic regression

Variable	*Adjusted OR$^{\#}$ (95% CI)*
Age at entry	1.06 (1.02 – 1.10)**
Gender (male/ female)	1.22 (0.53 – 2.82)
Length of employment	0.91 (0.87 – 0.96)**
Management commitment to health and safety	0.91 (0.84 – 0.98)*
LBP during previous 12 months and supervisor climate interaction:	
LBP during previous 12 months (zero supervisor score)	
No	1.00
Yes: work not affected	1.31 (0.59 – 2.87)
Yes: lost time	3.88 (1.47 – 10.26)**
Supervisor climate	
No LBP during previous 12 months	0.96 (0.86 – 1.07)
LBP during previous 12 months: work not affected	1.05 (0.93 – 1.18)
LBP during previous 12 months: lost time	0.75 (0.61 – 0.93)**

Hosmer-Lemeshow goodness of fit statistic for model = 4.64, degrees of freedom=8, P = 0.7951
 # Adjusted for all variables listed

10.2.3 Cox regression

Altogether, 515 participants were followed-up for a total of 227,265 days (Table 98). Note that this differs slightly from the follow-up time for LBP due to differences in the occurrence of missing responses to the two questions and hence in the recorded number of days of exposure. During the study, there were 60 episodes of lost time due to injury other than LBP.

Table 98 Descriptive statistics for survival-time data: lost time due to injury other than LBP

	Total	***Per subject***			
		mean	***min***	***median***	***max***
Number of subjects	515				
Time to exit		443.42	1	548	644
Subjects with lost time	55				
Days of lost time (N = 55)	2,450	44.55	1	18	285
Days at risk	227,265	441.29	1	548	644
Cases	60	0.12	0	0	3

LBP experience before the study was significantly associated with lost time due to injury during the study period (Table 99). Participants that had lost time due to LBP before the study had four times the risk of experiencing a period of lost time due to injury during the study as compared to those who had no LBP before the study (HR = 4.1, 95% CI 2.2 – 7.6). There was a significant trend of increasing risk of lost time due to injury with increasing age (P = 0.003), which was not observed when lost time due to LBP was investigated. In addition to this, length of employment showed significant decreasing risk (P = 0.005) and daily travel time showed significant increasing risk (P = 0.023). There were no lifestyle factors associated with losing work time due to injury, but regular exercise had previously been found to be associated with a reduced risk of lost time due to LBP (Table 55). Both supervisor climate and psychological work load were associated with lost time due to injury (Table 99), along with an increase in risk if trouble had been experienced in the previous three months in the neck and shoulders, or elbows and wrists/ hands (Table 99).

The final Cox regression model for lost time due to injury (Table 100) differed from that of lost time due to LBP (Table 55). Unlike the LBP model, there was no decrease in risk for females as compared to males, regular exercise was not protective, and there was no interaction between LBP experience and BMI. Instead, having lost time due to LBP in the previous 12 months significantly increased the risk of lost time due to other injury. It is possible that this may be related to the fact that a significant proportion of the non-LBP injuries were injuries to other parts of the musculoskeletal system.

Both Age and the Supervisor climate psychosocial variable were included in the LBP model but were not significant. By contrast, in the 'other injury' model, there was a significant increase in risk with increasing age, and significant decrease in risk with improved supervisor climate and increased length of employment. There was also a statistically significant association with having had trouble with the elbows or wrists/ hands three months before the study and losing work time due to injury.

Table 99 Crude and adjusted HRs for lost time due to injury other than LBP , estimated using Cox regression

	Days at risk	*Cases*	*HR (95% CI)*	*Adjusted HR*$^{\#}$ *(95% CI)*
Personal variables				
LBP during previous 12 months				
No	128,483	23	1.0	
Yes: work not affected	69,926	16	1.3 (0.7 – 2.4)	
Yes: lost time	28,807	21	4.1 (2.2 – 7.6)**	
P-value for continuous model			< 0.0001**	
Gender				
Male	183,361	44	1.0	
Female	43,855	16	1.5 (0.8 – 2.9)	
Age (years)				
< 30	42,380	3	1.0	
30 –	82,721	19	3.3 (1.0 – 11.0)	
40 +	101,548	38	5.4 (1.7 – 17.2)**	
P-value for continuous model			0.003**	
Length of employment (years)				
< 1	27,006	10	1.0	1.0
1 –	82,725	23	0.8 (0.4 – 1.6)	0.6 (0.3 – 1.2)
5 –	41,374	11	0.7 (0.3 – 1.7)	0.5 (0.3 – 1.0)
10 +	74,022	15	0.6 (0.3 – 1.2)	0.3 (0.1 – 0.6)**
P-value for continuous model			0.166	0.005**
Daily travel time (min.)				
0	20,892	2	1.0	1.0
1 –	96,836	18	2.0 (0.5 – 8.3)	1.7 (0.4 – 7.2)
30 –	71,057	24	3.5 (0.9 – 14.6)	2.6 (0.6 – 10.7)
60 +	38,431	16	4.3 (1.0 – 18.2)*	3.3 (0.8 – 13.9)
P-value for continuous model			0.010**	0.023*
Psychosocial variables				
Supervisor climate				
[-10, -5]	35,833	16	1.0	1.0
[-5, 0]	63,728	20	0.7 (0.4 – 1.4)	0.6 (0.3 – 1.1)
[0, 5]	81,112	15	0.4 (0.2 – 0.9)*	0.4 (0.2 – 0.8)**
[5, 10]	37,925	4	0.2 (0.1 – 0.7)**	0.3 (0.1 – 0.7)**
P-value for continuous model			< 0.0001**	0.001**
Psychological work load				
[-10, -5]	20,199	7	1.0	1.0
[-5, 0]	61,110	21	1.0 (0.4 – 2.2)	0.9 (0.4 – 1.9)
[0, 5]	86,584	20	0.7 (0.3 – 1.5)	0.8 (0.4 – 1.6)
[5, 10]	50,705	7	0.4 (0.1 – 1.1)	0.4 (0.2 – 1.1)
P-value for continuous model			0.002**	0.016*

	Days at risk	*Cases*	*HR (95% CI)*	*Adjusted HR$^{\#}$ (95% CI)*
NMQ				
Trouble during previous three months				
Neck and shoulders	129,095	21	1.0	1.0
No	93,904	38	2.5 (1.4 – 4.3)**	2.0 (1.1 – 3.5)*
Yes				
Elbows and wrists/ hands				
No	136,680	26	1.0	1.0
Yes	88,134	33	2.0 (1.2 – 3.3)*	1.9 (1.1 – 3.1)*

 # Adjusted for age, gender, and previous LBP

Table 100 Cox regression final personal variables model for lost time from injury other than LBP

Variable	*Adjusted HR$^{\#}$ (95% CI)*
Age at entry	1.05 (1.02 – 1.08)**
Gender (male/ female)	1.37 (0.74 – 2.54)
Supervisor climate	0.93 (0.89 – 0.98)**
Length of employment	0.93 (0.89 – 0.97)**
Trouble with arms[†] during previous three months (No; Yes)	1.72 (1.04 – 2.86)*
LBP during previous 12 months	
No	1.00
Yes: work not affected	1.19 (0.60 – 2.35)
Yes: lost time	3.93 (2.11 – 7.33)**

Test of proportional hazards assumption for model: $\chi2 = 6.13$, degrees of freedom = 7, P = 0.5242
 # Adjusted for all variables shown
† Elbows and wrists/ hands

10.2.4 AFT modelling

Altogether 55 participants lost 2,450 days of full work duties due to injury other than LBP (Table 101). There were 60 episodes of lost time, all of which returned to full duties before the end of the study period. The mean time to return to full duties was 41 days (greater than the 26 days for lost time due to LBP), with a median of 15.5 days. The log–normal AFT model was again used.

Table 101 Duration of lost time due to injury other than LBP

	Total	*Per subject*			
		mean	*min*	*median*	*max*
Number of subjects	55				
Number of periods of lost time	60				
Return to work	60				
Duration of lost time (days)	2,450	40.83	1	15.5	285

LBP experience before the study was not associated with duration of lost time due to non-LBP injury (Table 102). Those who were less than 30 years of age had statistically significant smaller duration of lost time due to these injuries than those who were 30 to 39, or 40 plus years of age. However, these TRs were based on just three observations in the less than 30 years of age category and should therefore be treated with caution. Regular exercise, whether or not this was aerobic, statistically significantly increased the duration of lost time due to injury. This was not found to be significant when investigating duration of lost time due to LBP, where BMI was the only statistically significant variable.

The final model for duration of lost time due to injury (Table 103) differed from that of LBP (Table 64). Those who regularly exercised lost around three times more work time than those who did not (TR 3.16, 95% CI 1.64-6.09). There were statistically significant interactions between age and length of employment, gender and influence and control over work, and LBP experience and management commitment to health and safety.

Table 102 Crude and adjusted TRs for lost time due to injury other than LBP , estimated using AFT models

	Days of lost time	*Return to full duties*	*Median return time*	*TR (95% CI)*	*TR (95% CI)*
Personal variables					
LBP during previous 12 months					
No	964	23	18.0	1.0	
Yes: work not affected	608	16	12.0	0.9 (0.3 – 2.4)	
Yes: lost time	878	21	22.0	1.0 (0.4 – 2.7)	
P-value for continuous model				0.990	
Gender					
Male	1,726	44	13.5	1.0	
Female	724	16	27.5	1.5 (0.6 – 4.0)	
Age (years)					
< 30	6	3	2.0	1.0	
30 –	795	19	15.0	7.1 (2.7 – 18.4)**	
40 +	1,649	38	20.5	9.8 (4.8 – 20.0)**	
P-value for continuous model				0.115	
Exercise regularly					
No	463	25	4.0	1.0	1.0
Yes	1,987	35	32.0	4.4 (2.2 – 9.0)**	5.0 (2.6 – 9.8)**
Regularly do aerobic exercise					
No	548	29	4.0	1.0	1.0
Yes	1,902	31	37.0	4.2 (2.1 – 8.6)**	4.5 (2.2 – 9.2)**
Regularly do non-aerobic exercise					
No	1,642	52	12.0	1.0	1.0
Yes	808	8	64.0	5.7 (2.5 – 12.8)**	6.7 (2.9 – 15.5)**

Table 103 Final personal variables model for time to return to full duties after starting a period of lost time due to injury other than LBP using AFT models

Variable	*Adjusted TR$^{\#}$ (95% CI)*
Regularly exercise (No; Yes)	3.16 (1.64 – 6.09)**
Age and length of employment interaction:	
Age (mean length of employment)	1.02 (0.98 – 1.06)
Length of employment (mean age)	1.10 (1.04 – 1.16)**
Interaction term	0.99 (0.99 – 0.99)**
Gender and influence and control over work interaction:	
Gender (male/ female) (zero score for influence)	0.68 (0.34 – 1.37)
Influence and control over work (male)	1.14 (1.06 – 1.23)**
Influence and control over work (female)	0.95 (0.83 – 1.09)
LBP experience and management commitment to health and safety interaction:	
LBP during previous 12 months (zero management score)	
No	1.00
Yes: work not affected	0.65 (0.31 – 1.34)
Yes: lost time	1.21 (0.64 – 2.27)
Management commitment to health and safety	
No LBP during previous 12 months	1.17 (1.09 – 1.26)**
LBP during previous 12 months: work not affected	0.99 (0.88 – 1.11)
LBP during previous 12 months: lost time	0.94 (0.86 – 1.04)

 # Adjusted for all variables listed

11 DISCUSSION

11.1 INTRODUCTION

This study is a prospective evaluation of the ability of the 1991 NIOSH Lifting Equation designed primarily to predict the incidence of absence from work due to LBP. It is based on a protocol developed in the USA by Liberty Mutual Research Institute for Safety and Texas Tech University.

11.2 STRENGTHS OF THE STUDY

Liberty Mutual / Texas Tech created a strong protocol with:

- A prospective study design that sought to collect time to event data;
- The direct measurement at baseline of task variables for the jobs included in the study rather than relying on surrogates such as job title;
- Three-monthly (i.e., regular and frequent) follow-up of participants to minimise recall problems in capturing accurate outcome data;
- An 18 month follow-up period;
- Modification of the study design to include a wider range of jobs than originally planned;
- Specification of sophisticated modelling techniques to investigate the relationships between potential predictors and the outcome variables.

The modifications to the protocol made by HSL were intended to further strengthen the study through:

- Addition of a psychosocial questionnaire at baseline;
- Addition of the HSL revision of the NMQ at baseline, including asking about the work-relatedness of MSD trouble.

The original protocol scored 8/12 on the methodological scoring system set out by Davis and Heaney (2000) . The additions in the HSL protocol brought this to 11/12.

Other factors that strengthened the HSL study were:

- Strict inclusion criteria to eliminate jobs that would be unsuitable for analysis;
- Inclusion criteria for subjects intended to minimise dropout;
- All site visits and measurements being carried out by one individual;
- Provision of an encouragement to take part through the offer of a free t-shirt;
- The wide variety of tasks included in the study;
- A simple follow-up letter that was easy for the recipient to complete and return at no cost to themselves;
- Asking in the follow-ups about LBP that had not caused work-loss;
- Asking in the follow-ups about the occurrence of injuries at work;
- Repeated reminders to participants that did not reply to follow-up letters, by both post and phone;

- Not automatically treating non-responders to follow-up as dropouts;
- Continued inclusion of participants that changed job to another job that was in the study;
- Very high response rates at follow-up;
- Follow-up of companies to capture absence or job change data not reported by individual participants;
- Checking RIDDOR reports made to HSE;
- Systematic recording of responses received from individuals and consequent highly accurate information on who should be followed up / sent reminders and when;
- Lower dropout than Liberty Mutual;
- Reasonable incidence rate;
- During the study, HSL began to employ staff with professional qualifications in epidemiology who were able to assist with the analysis.

11.3 LIMITATIONS OF THE STUDY

The weaknesses in the study design were:

- The tasks were only measured at baseline, meaning that changes to a job were not captured unless the participant reported a job change at one of the follow-ups so it cannot be guaranteed that exposure to manual handling was constant throughout the study.
- The limited duration of the baseline task measurements (typically up to 15 minutes observation) will have failed to capture job variability that had not been identified in the preliminary visits or was not mentioned by the workers that were videoed.
- The psychosocial questionnaire and the NMQ were only used at baseline. This meant that changes in the psychosocial state of an individual were not measured. Nor could changes in the MSD status away from the low back be detected, except from injury reports.
- The protocol did not include the detailed follow-up of reports of problems or the contacting of participants to clarify ambiguous or missing data.

Inevitably, problems were experienced in the execution of the study:

- The difficulties experienced in recruiting subjects meant that the sample size achieved was only about half of the revised target of 1000, which reduced the statistical power of the study.
- It was found that very few employers have large numbers of workers performing identical tasks. Moreover, there were high refusal rates by potential participants in some suitable jobs, resulting in some potential sites not being included, and in there being small numbers of participants in many jobs. These factors made recruitment of firms / subjects and collection of job data very time-consuming.
- The level of detail required to characterise the manual handling requirements of a job meant that gathering the data was a lengthy process so much of the data were captured on video to minimise time on-site. The off-site conversion of the gathered task data into the form needed for statistical analysis was a highly complex and very labour intensive process.

- There was a higher dropout / change of job / loss to follow-up than anticipated at the planning stage of the study.
- There was incomplete analysis of task data. The analyses reported are based on task data for 355 subjects out of the 515 recruited at baseline.
- Analysis concentrated on the incidence of lost time (absence + light duties) rather than separate analyses of the incidence of absence and the incidence of light duties without absence.
- Errors were made in interpolating frequencies of handling when calculating CLI values for SEVs of low frequency tasks. It appears that the consequent errors in the CLI are typically of the order of ±0.1, with the largest observed being in the ±0.3 region. Given that this typically affected one task per job and only affected a proportion of the jobs, and given the wide range of CLI values obtained, it is likely that the overall error was small.

11.4 METHODOLOGICAL ISSUES

11.4.1 Measurement of exposure at baseline

The initial version of the baseline questionnaire included a question about how much time the respondent spent in the course of a normal workday performing manual handling actions. This proved to be worthless as a question due to differences in interpretation by respondents. More broadly, Leclerc (2005) noted that "there is still no consensus about the validity of questionnaire data to assess postural load". It became apparent that it is almost impossible for an individual to report accurately their exposure on a questionnaire. Firstly, there is the recall issue, and secondly there is the definition issue, which makes writing a suitable question set very difficult. Thus, two individuals might spend their whole working day on a task, such as palletising, which involves lifting, carrying, and lowering. However, depending on the non-manual handling aspects of the job, such as inspection and paperwork, one might be performing the handling task once every 5 minutes whereas the other might be performing it once every minute. They could legitimately say they are performing each action 100% of the day, but their exposures differ by a factor of five. Therefore, assessment of load needs detailed analysis, which is best done by observation over a representative part of the workday.

While questionnaires have been widely used to attempt to measure mechanical exposure and there have been attempts to construct valid indices for mechanical exposure using them (Balogh *et al.,* 2001), the experience gained with this project suggests that this, at the very least, is a task of enormous difficulty. Therefore one of the strengths of this project was the direct measurement of exposure at baseline, and that attempts were made to ensure that this was a representative measurement by excluding jobs with very variable exposures and jobs where changes were expected during the 18 months of the follow-up period.

11.4.2 Recall of symptoms

The three month follow-up period used by Liberty Mutual conveniently matched the three month recall period recommended for the NMQ (Ørhede, 1994) and allowed consistency of questions between the baseline and follow-up questionnaires. Miranda *et al.* (2006) reported the results of a longitudinal study that demonstrated the problems of recall of musculoskeletal problems over a six year period between baseline and follow-up. They found that recall of prior problems was strongly influence by current problems. They found that most of the participants who had reported pain at baseline were unable to recall it at follow-up. Forgetting was considerable even among those with current symptoms. However, over-recall was found among those with symptoms at follow-up, particularly among those with intermittent symptoms that did not cause problems with daily functioning. All the individuals who correctly recalled pain at baseline appeared to have chronic pain.

In the light of that study, it is clear that one of the strengths of this study is the frequent follow-up and the short duration of each follow-up period. Also, the use of a range of outcomes with different severities, including sickness absence, strengthens the data set since confirmation can be sought of objective events such as sickness absence.

11.5 IMPLICATIONS OF FINDINGS

11.5.1 Prediction of lost time due to LBP or reports of LBP

This study has demonstrated that there is no relationship between the CLI and either the incidence of lost time due to LBP (Figure 29) or the prevalence of LBP. The crude HR for the CLI obtained from the continuous model from the Cox regression (Table 67) is 1.0, with a 95% CI ranging from 0.9 to 1.1. These figures were not affected by adjusting for the covariates in the model. Identical ORs and CIs were found for reporting of LBP (Table 68). In other words, absolutely no increase in risk was found for a change in the CLI, and the confidence in this conclusion is high because of the very narrow CIs.

This means that the CLI is not useful as a method for assessing risk of LBP due to manual handling. Dempsey and Mathiassen (2006) are not the first to state that the 1991 equation is probably one of the most widely used quantitative assessment tools for manual handling, but the use does not appear to have been surveyed formally. While there are reports in the peer-reviewed literature of its use in industry (Auguston, 1995; Chung and Kee, 2000; Ciriello and Snook, 1999; Dempsey, 2003; Kucera *et al.,* 2008; Marklin and Wilzbacher, 1999; Schuijt *et al.,* 1997; Steinbrecher, 1994; Temple and Adams, 2000), the fact that they are relatively sparse reflects the facts that most users would not report its use and that no formal survey appears to have been reported. A case-control study (Sesek, 1999) deliberately chose not to use the CLI but to evaluate each lift individually.

Because of the negative finding of a lack of relationship between the CLI and reports of LBP, further analysis was carried out of the maximum value of the STLI (Figure 29) as this is the task deemed the most severe and therefore the largest contributor to the CLI. The crude HR for the STLI (Table 67) is also 1.0 with the 95% CI ranging from 0.8 – 1.3. Adjusting for the covariates in the model increased the HR slightly to 1.1 with the 95% CI becoming 0.9 – 1.4. While the CI is wider than for the CLI, it is still narrow and still includes the 1.0 value.

Similarly, it was found that, after adjustment for covariates in the model, there were no relationships between the STLI and the prevalence of reporting LBP (Table 68). This means that the STLI is also not useful as a method for assessing risk of LBP due to manual handling.

The value of maximum horizontal reach during lifting that contributed to the maximum STLI calculation was shown by the Cox regression to be a significant predictor of lost time due to LBP (HR = 1.2, 95% CI 1.0 – 1.5, after adjustment for the personal variables). The maximum vertical offset from a height of 750 mm (approx knuckle height) proved to be significant in the unadjusted Cox regression, but this disappeared after adjustment for covariates. This means that the study has demonstrated that at least one of the variables that contribute to the 1991 equation should be part of a risk assessment tool for manual handling. It has not yet been determined whether the values that contribute to the maximum STLI are the most appropriate single values to represent the variables that contribute to the equation when attempting to predict risk from single variables. Conceptually, it is possible that the individual parameters for either the most frequent task, or the task with the largest load × frequency combination should be used instead. Moreover, a larger sample size would give better estimates of the HRs for all these variables.

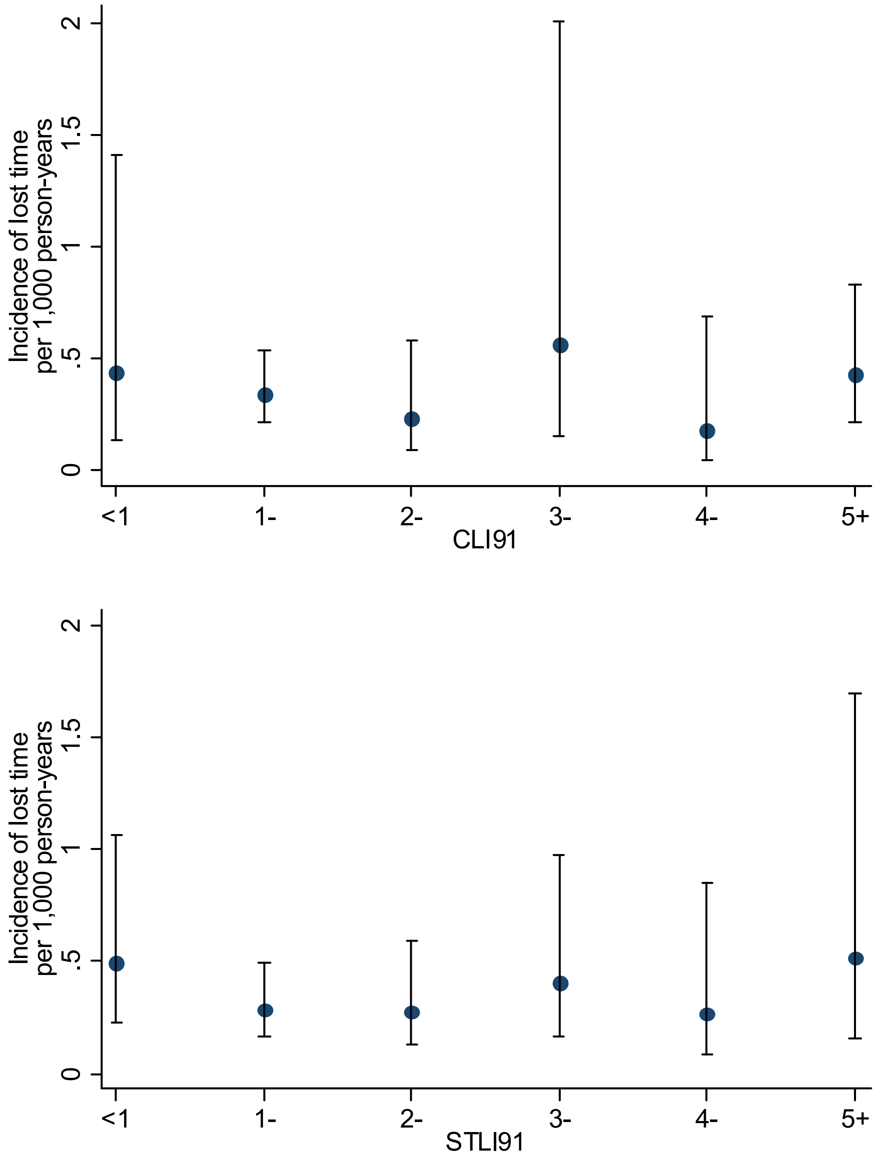


Figure 29 Incidence of lost time during the study period by CLI and STLI (Error bars represent 95% CIs)

These findings differ from those of the Waters *et al.* (1999). This was a cross-sectional study that found an OR of 2.45 (95% CI 1.29 – 4.85) for jobs with $2 < LI \leq 3$ for reporting LBP in the previous 12 months. Also, Wang *et al.* (1998) found a significant but low ($r = 0.392$, $P < 0.01$) correlation between the mean LI and workers' ratings of severity of low back discomfort. However it appears that they used a frequency weighted formula for calculating the composite index they used rather than the CLI formula specified by Waters *et al.* (1994) so the results are not easily compared.

The case-control study by Sesek (1999) found a very poor sensitivity of 17.6% for the LI threshold of 1.0. The specificity was high at 85.2%. Overall, approximately 85% of jobs were being classified as low risk by this threshold, whether or not they were high risk. Those findings are consistent with the findings of this study.

11.5.2 Other findings

The finding that a history of LBP is a strong predictor of future episodes of LBP (Table 39 and Table 48) was expected as this has been reported previously (Papageorgiou *et al.,* 1996).

The finding that that LBP that did not cause work loss was reported by approximately seven times as many individuals who took time off due to LBP agrees with the figures for GP consultation from the South Manchester Back Pain Study (Papageorgiou *et al.,* 1998). They found a one year cumulative episode incidence of 31.5% and a cumulative consultation rate of 4.5%, giving a ratio of 7.1:1. They suggested that the "association between low back pain and primary care consultation is not direct but mediated by other factors" and the same conclusion can therefore be drawn from this study about the relationship between LBP and work loss due to LBP.

A prospective study by Caragee *et al.* (2006) of a cohort at working individuals with personal factors giving a high risk of LBP found that of 196 LBP episodes associated with lifting, 39 (19.9%) resulted in a compensation claim, giving a 4:1 ratio.

11.6 THE STRUCTURE OF THE NIOSH EQUATION

11.6.1 Issues related to the CLI formula

Examination of the formula for calculating the CLI demonstrated that while it correctly handles changes in frequency due to adding tasks to a job, there appear to be major problems with other aspects of the formula. For a job including only two tasks, the CLI formula (1994) can be written as:

$$(13)\quad \mathrm{CLI} = \mathrm{STLI}_1 + \Delta \mathrm{LI}$$

where STLI_1 is the maximum STLI value, and

$$(14)\quad \Delta \mathrm{LI} = \mathrm{FILI}_2 \,/\, (1 \,/\, \mathrm{FM}_{2,1} - 1 \,/\, \mathrm{FM}_1)$$

where FILI_2 is the Frequency Independent Lifting Index for the second task; $\mathrm{FM}_{2,1}$ is the value of the Frequency Multiplier (FM) for the combined lifting frequency and FM_1 is the value of FM for the first task.

In other words, the CLI is calculated by taking the largest STLI and incrementing it by the FILI for each subsequent task, adjusted to take account of the increase in frequency. It is clear from the examples in the Applications Manual (Waters *et al.,* 1994) that this method does ensure that the correct values of FM are used for the overall frequency.

One issue that this project has not examined in detail is whether it is appropriate to increase the CLI by using the FILI in this way. Since STLI_1 is the STLI for the most severe task, then adding LI values and adjusting for the increased frequency can lead to the average lift being assessed as more severe than any individual lift and more severe than just increasing the frequency for the STLI_1 task. Calculation of "Single Equivalent Values" (SEV) for a variety of tasks, where either the horizontal or the vertical distance varies but all other variables are fixed, has shown this to occur.

One thing that has been found is that the CLI equation is not commutative. In other words, the order in which tasks are added affects the CLI value obtained. This was discovered when correcting values for a job with two tasks meant that the STLI for the previously more severe task decreased, making it the less severe task. As a result, the second, unchanged, task entered the CLI calculation first. Despite the severity of the job decreasing, the CLI actually increased.

This finding means that the CLI formula is mathematically fundamentally flawed and a new approach would be needed for a replacement composite risk formula. Approaches that have been recommended in the past include time-weighted averages (Ayoub and Mital, 1989).

11.6.2 Issues related to the multiplicative structure of the NIOSH Equations

The 1991 equation followed the 1981 equation in taking a weight and multiplying it by a series of values derived from task parameters.

(15) $RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$

As each of the multipliers can have maximum values of 1.0, the LC of 23 kg is the maximum possible value of the RWL. The RWL is then divided into the actual load to give the STLI.

The basis for using a multiplicative equation is a paper by Drury and Pfeil (1975). They proposed a model involving

> *"a base weight (WB) which is the maximum (under some criterion) which can be lifted under perfect conditions, multiplied by a series of factors to give the effects of the task variables."*

They described it as:

> *"a particularly simple model which assumes that all factors can be represented by a main effect only and that these factors interact in a multiplicative way."*

And went on that:

> *"The reasoning behind this is that in many instances similar ratios are obtained between performance in various conditions."*

They also reported a small (N = 5) validation study that used four factors (sex, age, height of the destination of the lift and awkwardness of handling) as a predictor of maximum acceptable weight of lift and had a very high predictive power ($r = 0.936$, $R^2 = 87.6\%$).

A multiplicative equation has been used to predict working heart rate from manual handling task parameters (Maiti and Ray, 2004) but the accuracy of the predictions is not reported. There are no other identified studies that attempt to validate a multiplicative model for manual handling risk assessment. Moreover the fact that the maximum STLI proves to be no use as a predictor of LBP suggests that the multiplicative approach should be rethought from scratch. Other prospective studies, such as the SMASH study carried out in the Netherlands (Hoogendoorn *et al.,* 2002b) have shown that a number of variables such as flexion and rotation of the trunk, lifting, and low job satisfaction are risk factors for sickness absence due to LBP.

Given that predictive models created using the various available regression techniques are usually based on linear, i.e., additive, models, it seems that a model that predicts overall risk from a manual handling operation should take this approach. This is assuming that it is valuable to predict the overall risk rather than identifying the hazardous features of the manual handling operation so that changes can be made to these factors.

11.6.3 Usability issues of the 1991 NIOSH Lifting Equation

As has previously been found (Dempsey, 2002; Wang *et al.,* 1998), a significant proportion of the tasks included in this study had one or more parameters outside the boundaries specified in the Applications Manual. Wang *et al.* (1998) described them as too stringent to accommodate many existing manual handling jobs. In this study, the formulae for the multipliers for horizontal reach, vertical position and frequency were extrapolated to allow the inclusion of jobs with out of range values. Dempsey (2002) also found that the variable nature of lifting operations made it difficult to make use of the equation in assessing actual jobs in workplaces. This study sought to recruit subjects in jobs where there was regular manual handling rather than very variable handling. However, problems were found due to the complexity of even relatively simple jobs.

11.7 IMPLICATIONS FOR EN AND ISO STANDARDS DERIVED FROM THE 1991 NIOSH LIFTING EQUATION

The ISO equation is effectively identical to the 1991 NIOSH equation. The EN equation has added multipliers that are intended to take account of three additional variables (one-handed handling, two person handling and additional tasks). Neither equation provides a method for compositing multiple tasks so neither has an equivalent to the CLI. However, the values that they calculate are conceptually similar to the STLI. It is therefore immediately apparent that the failure of the maximum STLI to predict LBP will also apply to these equations.

11.8 GENERAL IMPLICATIONS FOR METHODS OF ASSESSING RISK OF LBP

Even though one of the criteria for jobs to be included in the study was that they should not be very variable, in practice it was found that even simple tasks usually consist of more than one lifting operation. The focus on risk assessment of manual handling operations is usually on the risk from an individual task rather than on the overall probability of harm occurring to the individual because of the complexity of assessing overall risk and because identifying hazardous tasks allows action to be taken to reduce exposure. The danger of expecting too much from risk assessment methods must be borne in mind, as they may be insufficiently powerful to deal with complex workplaces (Dempsey and Mathiassen, 2006).

The NIOSH CLI was proposed in an attempt to provide an index of overall risk. Other than time-weighted averages, no other proposals for composite indices have been identified for other assessment methods. There appear to be only a few publications that report use of the CLI (Chung and Kee, 2000; Freivalds and Seth, 1996; Grant *et al.,* 1997; Mahone, 1993). This is no doubt in part due to the sheer complexity of the calculations involved. Therefore, it appears that the primary use of such overall risk indices would be in epidemiological studies such as this one. Any future attempt to validate any method of assessing risk from manual handling will need to develop suitable composite indices.

It must therefore be concluded that better methods of assessing risk of LBP from manual handling must be developed and that there should be a focus on creating better ways of combining multiple risk factors and of combining exposures to multiple tasks.

11.9 POSSIBLE FUTURE USES OF THE COLLECTED DATA

Data for this study were deliberately collected so that they would be compatible with the data collected using the original Liberty Mutual / Texas Tech proposal. This pooling and joint analysis of the two data sets has still to be carried out.

It would also be possible to use the data to test the predictive ability of the MAC tool and consideration has already been given to defining suitable composite indices. Similar analysis of other methods of assessing MSD risk such as REBA (Hignett and McAtamney, 2000) or the QEC (David *et al.,* 2008) would require a close examination of each method to define possible composite indices.

12 GLOSSARY

Term	*Explanation*
Accelerated failure-time model	A mathematical model that predicts the natural logarithm of the time to event from other variables. In this study, it was used to predict the duration of time lost from work.
Adjusted risk ratio	A risk ratio that has been modified to take account of the effects of confounding variables or covariates
Adjustment for confounders	Incorporating covariates into a mathematical model to control for their effect on the outcome of interest
Akaike Information Criterion (AIC)	A criterion for comparing the results of different logistic, proportional hazards or accelerated failure time regression models by estimating the most likely outcome. The lower the value, the better the model.
Attributable Fraction (AF)	The proportion of cases of a specific outcome that can be attributed to a specific cause.
Baseline	The point at which a subject entered the study, i.e. t=0. Note that subjects entered the study over an extended period but for the purpose of analysis are all treated as entering the study at t=0.
Binary variable	A variable with two possible values, usually 0 and 1 used to indicate Yes/No or True/False conditions.
Biopsychosocial approach	An approach to dealing with patients reporting problems such as LBP that considers the wider context of their job and lifestyle, not just the clinical signs and symptoms.
Categorical variable	A variable with several different possible responses that are not numerical. An example set of responses would be No; Yes, work not affected, Yes, put on light duties, Yes, took time off work. The different responses may be represented by whole numbers, such as 1, 2, 3, 4.
Confidence interval (CI)	A range representing the confidence that a measured mean value accurately represents the true mean of the variable. For a measured mean of 15.0 with a 95% CI from 14.5 to 15.5, there is a 95% chance that the true value is between 14.5 and 15.5 and the best estimate of the true value is 15.0. The width of a CI decreases as the size of the measured sample increases and increases as the standard deviation of the mean increases..
Confounder	A variable that affects the relationship between the predictor variable and the outcome variable.
Continuous variable	A variable with a numeric scale so the response can have any value on the scale, such as 1.372 or 4.256.
Covariate	A variable that varies at the same time as the variable of interest and may therefore affect the relationship between the variable of interest and the outcome variable.
Cox regression	Proportional Hazard Models of the probability of the incidence of an outcome (e.g., LBP). It takes into account the time that a subject has been in the study.
Crude risk ratio	A risk ratio that has not been adjusted to take account of the effects of confounding variables or covariates.
Disability	On the NMQ and hence in this study, this is defined as “musculoskeletal trouble” that has prevented someone “from carrying out normal activities (e.g., job, housework, hobbies)”.
Factor analysis	A statistical technique that examines relationships between variables with the aim of using a small number of variables to summarise a large number

Term	***Explanation***
	of variables.
Generalised Estimating Equations (GEEs)	An extension of logistic regression that permits analysis of outcomes that recur.
Hazard Ratio (HR)	The ratio of the absolute probabilities of two outcomes. Thus if two events had probabilities of 50% and 5% the Hazard Ratio would be 10.
Incidence rate	The rate of occurrence of new events of the outcome of interest (e.g., of episodes of lost time due to LBP)
Indicator variables	Variables coded to indicate whether a categorical variable is or is not equal to a particular value.
LBP experience	The reported history of LBP of an individual. In this study this usually refers to LBP in the 12 months before entering the study
Light duties	An episode where a participant in the study was at work but not did perform their normal duties due to either LBP or an injury at work.
Logistic regression	A regression model that predicts a binary outcome (e.g. below or above a threshold)
Lost time	Any episode or combination of episodes of time off or light duties that prevented a participant performing their normal work due to either LBP or an injury at work.
Low back pain (LBP)	Pain in an area of the back shown in the diagram accompanying the NMQ; otherwise not precisely defined.
Musculoskeletal trouble	On the NMQ and hence in this study, this is defined as “ache, pain, discomfort, numbness, tingling, or pins and needles” in a particular part of the body.
Nordic Musculoskeletal Questionnaire (NMQ)	A questionnaire developed in Scandinavia that uses a body map to ask respondents to report “musculoskeletal trouble” that they have experienced (Kuorinka *et al.,* 1987). HSE adapted it for use in the UK (Dickinson *et al.,* 1992). This study has further modified the HSE version.
Odds	The ratio of the probability of an event happening to the probability of it not happening. Odds of 9 to 1 means that in ten tests one outcome would be expected nine times and the other once.
Odds Ratio (OR)	The ratio of the Odds of two events or outcomes. This is obtained from techniques such as logistic regression. An OR of 1.0 means that both outcomes are equally likely.
Outcome variable	A measurement of an outcome of interest in a study, such as the incidence of LBP.
PAK	A Swedish psychosocial questionnaire developed by Johansson and Rubenowitz (1994). A modified version of it has been used in this study.
Prevalence rate	The proportion of a sample that report the presence of an outcome of interest (e.g., LBP in the previous 12 months)
Previous LBP	Reported experience of LBP in the 12 months prior to entering the study
Proportional Hazards Model (PHM)	A type of survival analysis where the probability of failure is assumed to be a function of the explanatory variables and unknown regression coefficients as well as a function of time. It therefore permits estimation of the effects of different covariates influencing the times-to-failure.
Psychosocial factors	Non-physical factors, such as relationships with fellow workers.
Relative Risk (RR)	A synonym for Hazard Ratio
Risk Ratio (RR)	A synonym for Hazard Ratio
Single Equivalent Value	A value of a parameter (e.g. Horizontal distance) for the NIOSH equation that gives the same Composite Lifting Index as a number of lifts where that

Term	***Explanation***
(SEV)	parameter varies. All other parameters are assumed to be constant.
Standard Deviation (SD)	A measure of the variability of a group of numbers.
Statistical power	The probability that a statistical test can detect a genuine difference between two conditions.
Statistical significance	A threshold (typically P = 0.05) used with statistical tests to determine if it is reasonable to believe that the difference between two conditions is due to chance.
Survival analysis	An epidemiological approach that examines how long a subject in the study survived before an event of interest (e.g., taking time off work due to LBP) occurred.
Survival time	The length of time that a subject survived in the study before an event of interest (e.g., taking time off work due to LBP) occurred.
Time off work	An episode where a participant in the study took time off work due to either LBP or an injury at work
Time Ratio	The ratio of two times, such as the duration of lost time from work.
Time to event	The time from the study baseline to the occurrence of an event of interest
Type 1 error	Accepting a statistically significant result of a statistical test of two conditions when there is not a real difference between them.
Type 2 error	Accepting a non-significant result of a statistical test of two conditions when there really is a real difference between them.
Work not affected	A participant reported LBP or other injury at work that had not resulted in light duties or taking time off work.

13 ACRONYMS AND ABBREVIATIONS

Abbreviation	*Meaning*
AIC	Akaike Information Criterion
AFT	Accelerated Failure Time
AL	Action Limit
AM	Asymmetry Multiplier
BMI	Body Mass Index
BS	British Standard
CI	Confidence Interval
CLI	Composite Lifting Index
CM	Coupling Multiplier
DALY	Disability-Adjusted Life Years
DF	Degrees of Freedom
DM	Vertical distance Multiplier
EN	European Norm
F	Frequency (lifts per minute)
FILI	Frequency Independent Lifting Index
FIRWL	Frequency Independent Recommended Weight Limit
FM	Frequency Multiplier
Fsum	Sum of values of F for multiple tasks
GAMs	General Additive Models
GEE	Generalised Estimating Equations
HM	Horizontal Multiplier
HR	Hazard Ratio
ISO	International Standards Organisation
LBP	Low Back Pain
LC	Load Constant
LI	Lifting Index
MAC	Manual handling Assessment Charts
MCAR	Missing Completely At Random
MPL	Maximum Permissible Limit
MSD	Musculoskeletal Disorders
NIOSH	National Institute of Occupational Safety and Health
NMQ	Nordic Musculoskeletal Questionnaire
OWAS	Ovako Working posture Analysis System
OR	Odds Ratio
PHM	Proportional Hazards Model
QEC	Quick Exposure Check
QIC	Quasi-likelihood under the Independence model Criterion
QIC_u	Quasi-likelihood covariate selection criterion
REBA	Rapid Entire Body Assessment

Abbreviation	*Meaning*
RH	Relative Humidity
RR	Risk Ratio or Relative Risk
RWL	Recommended Weight Limit
SD	Standard Deviation
SEV	Single Equivalent Value
SLI	Sequential Lifting Index
SMASH	Study on Musculoskeletal Disorders, Absenteeism, Stress, and Health
STLI	Single Task Lifting Index
STRWL	Single Task Recommended Weight Limit
TF	Time Fraction
TR	Time Ratio
VM	Vertical Multiplier
WHR	Working Heart Rate

14 APPENDIX 1 – INFORMATION LETTERS, CONSENT FORM AND QUESTIONNAIRES

Broad Lane, Sheffield, S3 7HQ
Telephone: 0114 2892000
Facsimile: 0114 2892500

HEALTH & SAFETY
LABORATORY

10 June 2002

Information for companies taking part in the HSE/HSL field evaluation of manual handling criteria

The Health and Safety Laboratory (HSL) is carrying out a project on behalf of HSE to evaluate existing US and proposed European and International guidelines for manual handling operations, particularly lifting and lowering. We are collaborating with Liberty Mutual Research Center and Texas Tech University in the USA who are carrying out a similar study.

We hope to determine the relationship between the demands of manual handling tasks and the likelihood of injury. Eventually, the results of the study will be used to (re)design workplaces to reduce the risks of workers being injured by their jobs.

We are looking for a range of companies from across the UK to participate in the study. The study will involve us recording the manual handling tasks that 1000 workers carry out on a regular basis. We will then record any injuries they suffer at work over the following 18 months. We would like to recruit in the region of 50 workers per firm.

What we will do

1. With the help of participating companies, we will identify jobs involving manual handling tasks that are suitable for inclusion in the study.
2. We will ask workers who perform these jobs, and that agree to participate, to complete a consent form and a questionnaire. The questionnaire will include questions about their health, their work activities and their perception of their work.
3. We will take measurements of the work tasks these workers carry out which involve manual handling.
4. We will record any injuries that these workers suffer at work over the following 18 months. After 9 months and 18 months we will ask companies to send us details of any accidents that have happened to these workers in the intervening period and of any sick leave they have taken as a result. We will also ask them to let us know if there have been any major changes in the jobs included in the study.
5. We will also contact the workers at home every three months over the 18 months to ask whether they are still working in the same job and about any injuries at work.

Selection criteria for jobs

We need to study a variety of job types with different manual handling demands, not just very stressful jobs. For inclusion in the study the jobs will have to meet the following criteria:

1. Manual handling must occur as a regular daily activity, with each worker performing at least 25 lifts / lowers per day
2. Jobs must be expected to continue in their present form for least 18 months.
3. Jobs should have at least 10 workers performing them, even if not all of them are included in the study.
4. Jobs must not vary with the time of year or be seasonal or have job rotation periods of more than one week.
5. Jobs should mostly be the same from day to day so that the data we collect are a reasonable representation of what the worker does every day.
6. Preferably, jobs should include few component tasks so that they involve only a few distinct manual handling operations.
7. Jobs must not involve substantial vehicle driving.
8. Jobs must not involve patient handling.
9. Individual manual handling operations must be carried out by either a single person or, at most, a team of two people.

Types of jobs

We will study jobs that fall into the following four categories. The 'standard jobs' category is the ideal for the study but the others are also acceptable.

1. *Standard jobs*

These are jobs in which the manual handling tasks that are performed from day to day are identical or very similar, i.e., the weight, hand height, etc., for each task are quite stable. Examples include assembly tasks involving lifting or lowering during each cycle, and palletising tasks of the same or similar products.

2. *Variable weight jobs*

These are jobs in which the manual handling tasks performed remain relatively stable, but the weight changes. In this case, we will need detailed information on the way the weight varies. For example, a worker in a machine shop may operate a certain type of metal removing machine (such as a lathe or mill) approximately once every five minutes. The process may require the worker to lift the stock into and out of the machine, but the weight will vary depending upon the product.

3. *Warehousing / complex jobs*

These are jobs that involve many different types of lifts / lowers and different loads. Other than exclusively warehouse picking jobs, there are situations in which workers perform very large numbers of distinct manual handling tasks ("complex" jobs). An example would be unloading trucks (assuming the same worker is not the driver, since significant driving excludes a job).

4. Job rotation schemes

Situations where workers rotate between two or more jobs are acceptable for the study if the rotation schedule is regular and on a daily or weekly basis rather than a monthly or seasonal basis. At least one of the jobs in a rotating schedule needs to have a significant manual handling component. However, we will require some information on each of the rotations.

Subject participation

We are required to make sure that participation by individual workers in this study is completely voluntary. Individual workers may decline to take part in the study without penalty or question. They are also free to refuse to answer any individual question and can drop out from the study at any time without saying why.

We want both men and women to take part. There is no age limit or health status restriction except that we will not include women who are pregnant or who have had a baby in the last six months. (This is only because pregnancy itself can cause back pain). Individuals that do take part will need to:

1. Be full-time employees; and
2. Have at least one week of experience in their current job; and
3. Expect to stay in this job for the next 18 months.

Use of collected data

We will enter the data we collect into a computer database. Firms and individuals will be identified in this using code numbers. We will keep a separate database of individuals' and employers' names and addresses and code numbers. We will keep all data we collect for at least ten years. Participants have a right under the Data Protection Act to see any personal data we hold on them.

We will give our partners in the USA access to the main database but we will not give them access to the database of names and addresses. We will not let anyone else outside HSE see the personal data of individuals without their specific permission.

HSE/HSL reports and any external publications or presentations we produce will not refer to individuals or companies by name. Instead, we will present the results in a manner that summarises or averages the data.

Use of photographs and video material

As part of our collection of information we would like to videotape or photograph manual handling tasks. We will keep photographs and video for at least ten years. Each photograph will be identified by a code number.

We may want to use photographs of individuals in publications or presentations. If we do so, we will do our best to make sure that they cannot be recognised, but it is possible that somebody may still recognise them. We will only use photographs or video material in this way with the consent of the individual shown and with the consent of the firm where the pictures were taken. We fully understand if firms or individuals do not want pictures to be used in these ways.

Risks and benefits

Individual workers will be doing their usual jobs and will not be exposed to any risks beyond those they encounter under normal working conditions. Individual workers and firms will receive no direct benefit from participating in this study but the information gained may result in the improved health of workers who perform manual handling tasks.

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.

About HSL

HSL is a scientific laboratory which is part of HSE. We therefore always inform local Factory Inspectors before visiting premises they have powers to inspect. They may choose to accompany us on any visit. However, the purpose of this study is to carry out scientific research into the risks of manual handling, not to carry out inspections.

Conduct of the study

If you have any concerns about the way we carry out this study you may contact Dr R Rawbone, the secretary of the HSE Research Ethics Committee which approved this study, directly on 0151 951 4555.

We will be willing to answer questions about the study either when we visit firms, or afterwards. You can contact me by post at HSL at the address at the top of this letter or by phone, fax or email.

Dr Andrew Pinder
Direct Tel: 0114 289 2594
Direct Fax: 0114 289 2526
email: Andrew.Pinder@hsl.gov.uk

Broad Lane, Sheffield, S3 7HQ
Telephone: 0114 2892000
Facsimile: 0114 2892500

HEALTH & SAFETY
LABORATORY

May 2002

Information for volunteers taking part in the HSE/HSL field evaluation of manual handling tasks

The Health and Safety Laboratory (HSL) is carrying out a project on behalf of HSE to evaluate existing US and proposed European and International guidelines for manual handling operations, particularly lifting and lowering. We are collaborating with Liberty Mutual Research Center and Texas Tech University in the USA who are carrying out a similar study.

We hope to determine the relationships between the demands of manual handling tasks and the likelihood of back pain and injury. Eventually, the results of the study will be used to (re)design workplaces to reduce the risks of workers being injured by their jobs.

The study will involve a variety of firms across the UK. We want to include 1000 workers in a range of jobs requiring manual handling as a regular daily activity. We will identify suitable jobs with the help of the participating firms.

Your participation

You do not have to take part in this study and your job will not be affected in any way if you do not. If you do take part, you can refuse to answer any individual question and can drop out of the study at any time. You do not have to say why.

We want both men and women to take part. There is no age limit or health status restriction except that we will not include women who are pregnant or who have had a baby in the previous six months. (This is only because pregnancy itself can cause back pain). We will ask you to take part if:

1. You are a full-time employee; and
2. You have at least one week of experience in your job; and
3. You expect to stay in this job for the next 18 months.

We will ask you to do the following:

1. Sign a consent form.
2. Fill in an initial four page questionnaire. This asks about yourself and your job, about any musculoskeletal injuries or problems you may have had in the last year, and about your attitudes to your work.
3. Volunteer to help us take measurements of your work tasks that involve manual handling. This will involve being filmed on video. We expect that this will need at most two or three people per job.
4. Fill in a one page questionnaire every three months for the next 18 months. This checks that you are still working in the same job and asks about any recent back pain or injuries at work. We will post it to your home address, with a reply-paid envelope for you to send it back to us. If we don't get a reply from you within two weeks, we will try to contact you by phone to ask these questions. We may also phone you to ask you more details about your responses to the questions.

Use of collected data

We will enter the data we collect from you into a computer database. You will be identified in this by a code number. We will keep a separate database of individuals' and employers' names and addresses and code numbers. We will keep all data we collect for at least ten years. You have a right under the Data Protection Act to see any personal data we hold on you.

Your employer will need to know that you are taking part in the study so that we can check their accident records, but **we will not give them access to personal data we gather from you**. We will give our partners in the USA access to the main database but we will not give them access to the database of names and addresses. We will not let anyone else outside HSE see your personal data without your specific permission.

HSE/HSL reports and any external publications or presentations we produce will not refer to you or your employer by name. Instead, we will present the results in a manner that summarises or averages the data.

Use of photographs and video material

As part of our collection of information we may videotape or photograph as you perform your job. We will keep photographs and video for at least ten years. Each photograph will be identified by a code number but not your name.

We may want to use photographs of you in publications or presentations. If we do so, we will do our best to make sure that you cannot be recognised, but it is possible that somebody may still recognise you. We will only use photographs or video material of you in this way with your consent and with the consent of the firm where the pictures were taken. We fully understand if you do not want your picture to be used and the consent form allows you to indicate this.

Risks and benefits

Since you will be doing your usual job, there will not be any risks beyond those you encounter under normal working conditions. You will receive no direct benefit from your participation in this study but the information we obtain may result in the improved health of workers who perform manual handling tasks.

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.

Conduct of the study

If you have any concerns about the way we carry out this study you may contact Dr R. Rawbone, the secretary of the HSE Research Ethics Committee which approved this study, directly on 0151 951 4555.

We will be willing to answer questions about the study either when we visit firms, or afterwards. You can contact me by post at HSL at the address at the top of this letter or by phone, fax or email.

Dr Andrew Pinder
Direct Tel: 0114 289 2594
Direct Fax: 0114 289 2526
email: Andrew.Pinder@hsl.gov.uk

Confidential : Return to HSL or HSL staff only

Broad Lane, Sheffield, S3 7HQ
Telephone: 0114 2892000
Facsimile: 0114 2892500

HEALTH & SAFETY LABORATORY

Reference number:

VOLUNTEER CONSENT FORM

I, ☐ *(name in block capitals)* have read the INFORMATION FOR VOLUNTEERS for the study entitled:

HSE/HSL field evaluation of manual handling tasks

I am willing to:

- Fill in an initial questionnaire;
- Have measurements taken of my work tasks;
- Complete a follow-up postal questionnaire every three months for 18 months;
- Allow information not identifiable with me to be presented at meetings and published so that it can be useful to others.

YES ☐ NO ☐
(please initial one box)

I am willing to be filmed (video and/or photographs) while carrying out my job.

YES ☐ NO ☐
(please initial one box)

(We wish to record video and take photographs of one or two individuals per job studied. These pictures may be used for illustration purposes in HSE reports and any subsequent journal articles. We will make every effort to preserve your anonymity, but we cannot guarantee this.)

I understand that all personal data will be kept confidential in accordance with the Data Protection Act.

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

I understand that if I have any concerns about the conduct of the study I may contact Dr R Rawbone, the Medical Secretary of the HSE Research Ethics Committee, directly on 0151 951 4555.

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

SIGNATURE **DATE**

Signature of member of study team Date

This project has been cleared by the HSE Research Ethics Committee.
Signature of Chairman (Dr P Graham) Date

Please return this form in the FREEPOST envelope to:
Dr Andrew Pinder, Health and Safety Laboratory, FREEPOST NEA 10343, Sheffield, S3 7ZZ

Reference number:

HEALTH & SAFETY
LABORATORY

WORKER SURVEY: FIELD EVALUATION OF MANUAL HANDLING TASKS

Firm

Name **Date** ☐☐ ☐☐ 200☐

Home address

Postcode

Phone: Home **Mobile**

PERSONAL DETAILS

1	Are you male or female?	Male 1☐ Female 2☐
2	What is your date of birth?	☐☐ ☐☐ 19☐☐
3	How much do you weigh?	☐ stones + ☐ pounds, or ☐ kg
4	How tall are you?	☐ feet + ☐ inches, or ☐ cm
5	Are you right or left handed?	1☐ Right handed 2☐ Left handed 3☐ Able to use both hands equally

ABOUT YOUR JOB

6	a. What is your job?	
	b. Which area/line/cell do you work in?	
7	When did you start working for this employer, either permanently or temporarily?	☐☐ ☐☐ ☐☐☐☐
8	On average, how many hours a week do you work? Include overtime but not your main meal break.	☐ hours per week
9	a. What are your normal working hours?	
	b. If your shift changes regularly, what is the pattern?	
10	What **tasks** do you do regularly that involve lifting, lowering, pushing, pulling, holding or carrying actions? How long do you spend doing each task on a normal day?	Tasks | Hours per day
11	On average, how long do you spend **each day** travelling **to** and **from** work in a vehicle?	☐ hours + ☐ minutes
12	Have you suffered from low back pain **during the last 12 months**?	No 1☐ Yes 2☐ Work not affected 3☐ Put on light duties/short hours at work 4☐ Taken time off work

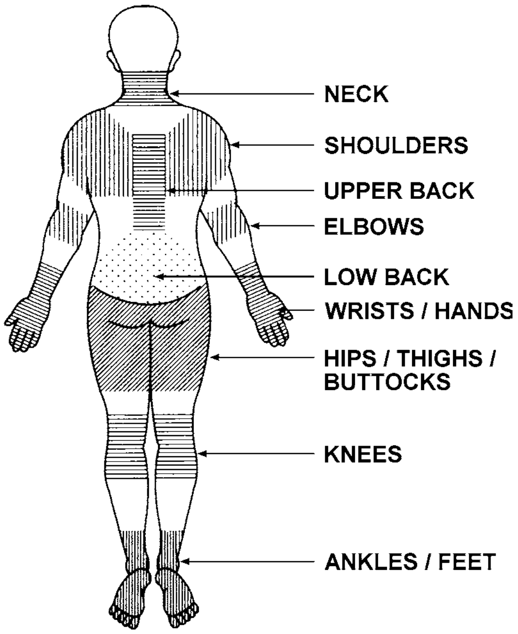
ABOUT YOU

13 Do you exercise regularly (on average three or more times per week) outside work? (Tick **all** types of exercise that you do regularly.)	No 1 ☐	Yes 2 ☐ Weight lifting 3 ☐ Running / jogging 4 ☐ Aerobics 5 ☐ Golf 6 ☐ Any team sport (e.g., football) 7 ☐ Others (specify) ☐
14 Do you currently smoke cigarettes?	No 1 ☐	Yes 2 ☐
If yes,		
a. How many do you smoke?		☐ cigarettes per day
b. How long have you been a smoker?		☐ years + ☐ months
15 Do you ever wear a back belt (support or brace) while doing this job?	No 1 ☐	Yes 2 ☐ **Stretchable:** some types of nylon, any material that stretches when pulled 3 ☐ **Non-stretchable:** belts made of webbed nylon, leather, or other inelastic materials
If yes,		
a. When did you first start wearing it?		☐☐ ☐☐ ☐☐☐☐
b. How often do you wear it?		1 ☐ Always, or most of the time 2 ☐ Sometimes, or about half of the time 3 ☐ Very little, or not at all 4 ☐ Only when handling heavy loads
16 **Women only**: Are you pregnant or have you had a baby in the last six months?	No 1 ☐	Yes 2 ☐

MUSCULOSKELETAL DISORDERS

For each body area shown please use the tick boxes - ☐ - to answer each of the four questions on the next page. Please make sure you put one tick for each question.

The picture shows how the body has been divided. 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 (CONT)

Have you at any time during the **last three months** had **trouble** (such as **ache, pain, discomfort, numbness, tingling, or pins and needles**) in your:		Have you had this **trouble** during the **last seven days?**	During the **last three months** has this trouble **prevented** you carrying out normal activities (e.g., job, housework, hobbies)?	During the **last three months** has this trouble been **caused** or **made worse** by your job?
Neck	**1** No Yes 1☐ 2☐	**2** No Yes 1☐ 2☐	**3** No Yes 1☐ 2☐	**4** No Yes 1☐ 2☐ Caused 3☐ Made worse
Should-ers	**5** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**6** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**7** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**8** No Yes 1☐ 2☐ Caused 3☐ Made worse
Elbows	**9** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**10** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**11** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**12** No Yes 1☐ 2☐ Caused 3☐ Made worse
Wrists/ hands	**13** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**14** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**15** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**16** No Yes 1☐ 2☐ Caused 3☐ Made worse
Upper back	**17** No Yes 1☐ 2☐	**18** No Yes 1☐ 2☐	**19** No Yes 1☐ 2☐	**20** No Yes 1☐ 2☐ Caused 3☐ Made worse
Lower back (small of back)	**21** No Yes 1☐ 2☐	**22** No Yes 1☐ 2☐	**23** No Yes 1☐ 2☐	**24** No Yes 1☐ 2☐ Caused 3☐ Made worse
Hips/ thighs/ buttocks	**25** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**26** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**27** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**28** No Yes 1☐ 2☐ Caused 3☐ Made worse
Knees	**29** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**30** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**31** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**32** No Yes 1☐ 2☐ Caused 3☐ Made worse
Ankles/ feet	**33** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**34** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**35** No Yes 1☐ 2☐ Right only 3☐ Left only 4☐ Both	**36** No Yes 1☐ 2☐ Caused 3☐ Made worse

Please check you have answered **ALL** of the questions on this page, even if you have never had trouble in any part of your body.

WORK CHARACTERISTICS

Please tick the box that best expresses how you feel about each of the following aspects of your work.

		Strongly disagree 1	2	3	4	Strongly agree 5
1	You can influence how fast you work	☐	☐	☐	☐	☐
2	You can influence your working methods	☐	☐	☐	☐	☐
3	You can influence how work tasks are shared out	☐	☐	☐	☐	☐
4	You have control over the technical content of your work	☐	☐	☐	☐	☐
5	You can influence the rules and regulations at work	☐	☐	☐	☐	☐
6	You have sufficient contact with your immediate supervisor	☐	☐	☐	☐	☐
7	Your supervisor asks your advice on work-related problems	☐	☐	☐	☐	☐
8	Your immediate supervisor considers different viewpoints	☐	☐	☐	☐	☐
9	Your immediate supervisor provides sufficient information	☐	☐	☐	☐	☐
10	The communication climate in the organisation is good	☐	☐	☐	☐	☐
11	Your work is interesting	☐	☐	☐	☐	☐
12	Your work is varied	☐	☐	☐	☐	☐
13	You have opportunities to use your skills in your job	☐	☐	☐	☐	☐
14	You have opportunities to learn new things at work	☐	☐	☐	☐	☐
15	Overall, you feel happy in your work	☐	☐	☐	☐	☐
16	You have good contacts with your fellow workers	☐	☐	☐	☐	☐
17	You have opportunity to talk with fellow workers about the job	☐	☐	☐	☐	☐
18	You find the atmosphere at work cheerful	☐	☐	☐	☐	☐
19	You have opportunities to discuss work-related problems	☐	☐	☐	☐	☐
20	You consider your fellow workers to be your friends	☐	☐	☐	☐	☐
21	The amount of stress you are under at work is acceptable	☐	☐	☐	☐	☐
22	Your workload is acceptable	☐	☐	☐	☐	☐
23	Your job does not make you feel exhausted	☐	☐	☐	☐	☐
24	Your rest breaks at work are long enough	☐	☐	☐	☐	☐
25	You are not under too much mental strain at work	☐	☐	☐	☐	☐
26	Your employer worries about your health and safety	☐	☐	☐	☐	☐
27	Your employer tells you it is important to report accidents	☐	☐	☐	☐	☐
28	Your employer takes care to make your work safe	☐	☐	☐	☐	☐
29	Your employer checks regularly if your work is making you ill	☐	☐	☐	☐	☐
30	Your employer makes sure health and safety rules are followed	☐	☐	☐	☐	☐
		1 Strongly disagree	2	3	4	5 Strongly agree

Please check you have answered **ALL** of the questions on this page.

Thank you for completing this questionnaire

Harpur Hill Buxton
Derbyshire SK17 9JN
Telephone: 01298 218000
Facsimile: 01298 218590
Website: www.hsl.gov.uk

HEALTH & SAFETY
LABORATORY

25 February 2005

<TITLE> <INITIAL> <LAST_NAME>
<ADDRESS1>
<ADDRESS2>
<TOWN>
<COUNTY>
<POST_CODE>

Field evaluation of manual handling criteria

Dear <TITLE> <LAST_NAME>

We interviewed you at work on <ENTRY_DATE> as a part of a study we are carrying out to evaluate guidelines for jobs which involve manual handling (lifting, lowering, pulling and pushing, etc.)

We sent you the sixth and final follow-up questionnaire a few weeks ago. As we haven't yet had a response from you I am enclosing another copy of it. We will be very grateful if you will fill it in and return it immediately to me at HSL using the FREEPOST envelope enclosed. As this is the last follow-up, I would like to thank you again for taking part in this study.

Yours sincerely

Dr Andrew Pinder
Direct Tel: 01298 218353
Direct Fax: 01298 218394
email: Andrew.Pinder@hsl.gov.uk

Please note our address has changed to:

Health and Safety Laboratory
Harpur Hill
Buxton
SK17 9JN

FOLLOW-UP SURVEY 6: FIELD EVALUATION OF MANUAL HANDLING CRITERIA

PARTICIPANT NUMBER: **<REF_NO>** *25 February 2005 (R)*

1. Please check your contact details are correct.

<TITLE> <INITIAL> <LAST_NAME>
<ADDRESS1>
<ADDRESS2>
<TOWN>
<COUNTY> <POST_CODE>
Home phone **<HOME_PHONE>**
Mobile phone **<MOB_PHONE>**

New contact details

Name
Address
Postcode
Home phone
Mobile phone

2. Are you still working as a **<JOB_TITLE>** in/on the **<WORK_AREA>** for **<COMPANY>**?

Yes 1☐
No 2☐ Moved to another job
3☐ Job redesigned
4☐ Laid off
5☐ Made redundant
6☐ Injured
7☐ Illness
8☐ Other

a. If not, when did you stop doing this job? ☐☐ ☐☐ 200☐

3. Have you suffered from low back pain since <FUP_DATE5 >?

No 1☐
Yes 2☐ Work not affected
3☐ Put on light duties / restricted hours at work
from ☐☐ ☐☐ 200☐ to ☐☐ ☐☐ 200☐
4☐ Taken time off work
from ☐☐ ☐☐ 200☐ to ☐☐ ☐☐ 200☐

4. Have you been injured at work since <FUP_DATE5>?

No 1☐
Yes 2☐ Work not affected
Date of injury: ☐☐ ☐☐ 200☐
3☐ Put on light duties / restricted hours at work
from ☐☐ ☐☐ 200☐ to ☐☐ ☐☐ 200☐
4☐ Taken time off work
from ☐☐ ☐☐ 200☐ to ☐☐ ☐☐ 200☐

a. Type of injury

b. Part of body injured

Signature Date

Thank you for your time. Please return this page in the reply paid envelope to:

Dr Andrew Pinder
Health and Safety Laboratory
FREEPOST NEA 10343
BUXTON SK17 9YA

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Published by the Health and Safety Executive 11/11

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Prospective evaluation of the 1991 NIOSH Lifting Equation

An epidemiological prospective cohort study of the ability of the 1991 NIOSH Lifting Equation to predict loss of time from work due to low back pain (LBP) or to predict reports of LBP followed 515 industrial workers in jobs requiring manual handling for 18 months. Baseline measurements were made of their jobs, histories of musculoskeletal trouble and of psychosocial variables. Longitudinal analysis of tasks was based on 367 subject/job combinations.

The strongest predictor of future LBP was a history of LBP. No relationship was found between the Composite Lifting Index (CLI) and either the incidence of lost time due to LBP or the prevalence of LBP (adjusted Hazard Ratio (HR) = 1.0, 95% Confidence Interval (CI) 0.9 – 1.1). The CLI is not useful as a method for assessing risk of LBP due to manual handling.

The maximum value of the Single Task Lifting Index (STLI) gave an adjusted HR of 1.1 (95% CI 0.9 – 1.4). It too is not useful as a method for assessing risk of LBP due to manual handling.

There is a need to develop better methods of assessing risk of LBP from manual handling, focusing on ways of combining risk factors and exposure to multiple tasks.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

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