Evaluating change in exposure to risk for musculoskeletal disorders - a practical tool

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Evaluating change in exposure to risk for musculoskeletal disorders - a practical tool

Guangyan Li and Peter Buckle
Robens Centre for Health Ergonomics
EIHMS
University of Surrey
Guildford
Surrey
GU2 5XH

The aim of this research was to develop a user friendly, practical tool for the assessment of physical exposure to risks for work-related musculoskeletal disorders. Studies of existing methods and tools have been carried out to establish areas of agreement and of difference regarding approaches to the assessment of exposure. A prototype tool has been developed, tested, modified and validated in a number of ways based upon both simulated and real work tasks. A participatory approach involving 150 practitioners, has been used. The experimental studies have shown that the current format of the tool has a good sensitivity and usability, has an 'acceptable' or 'moderate agreement' for its inter-observer reliability, and a higher intra-observer reliability. The field studies have indicated that the tool is reliable, in a practical context, and suitable for a wide range of jobs. With a brief training period (self-learning) and some practice in using this method, assessment can normally be completed within ten minutes for each task. The tool will enable the effective evaluation of a workplace design, equipment evaluation and promote better equipment redesign in the future.

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SUMMARY

Physical exposure to risks for work-related musculoskeletal disorders has been described with a variety of measures, but most of these existing methods have been designed for research purposes. Further, they are based on the research experts' view of what risk factors are important and how they should be measured. The resultant methods have a number of disadvantages, such as the limitations on their use in different work situations, the problems with reliability and the fact that their use can be time consuming. The development and application of a user-friendly tool to assess musculoskeletal risk would have many advantages for those in organisations responsible for health and safety. For example, they would be able to assess the extent of exposure before and after an ergonomic intervention.

This research has investigated the users' needs for such a tool. Studies of the existing methods / tools have been carried out to establish areas of difference and of agreement regarding approaches to the assessment of exposure. A prototype tool has been developed, tested, modified and validated in a number of ways based upon both simulated and real work tasks. This process involved the help of 150 practitioners. The development process has conformed to a participatory approach wherever feasible. The experimental studies have shown that the current format of the 'tool' has a good sensitivity and usability, has an acceptable or 'moderate agreement' for its inter-observer reliability, and higher intra-observer-reliability. The field studies have indicated that the tool is reliable, in a practical context, and suitable for a wide range of jobs. With a brief training period (self-learning) and some practice in using this method, assessment can normally be completed within ten minutes for each task.

The tool will enable the effective evaluation of a workplace design, equipment evaluation and promote better equipment redesign in the future. It will, hopefully, be used to help prevent a wide range of work related musculoskeletal conditions from developing, as well as educating managers, engineers, designers, health and safety practitioners and other end users about the musculoskeletal risks in their workplace. Further improvement and validation of the tool with a wider range of practical jobs / tasks are proposed.
1. INTRODUCTION

1.1 BACKGROUND

Recent European Union and member state initiatives (e.g., Management of Health and Safety at Work Regulations, 1992; Manual Handling Operations Regulations, 1992) have led to substantial interest in the identification and control of risk factors for work-related musculoskeletal disorders. As a result, there has been increased interest in the undertaking of practical risk assessment and ergonomic interventions in the workplace.

The effect of such interventions can be evaluated in one of two ways. The first is to identify changes in the incidence of health problems. This focuses on the change in the "effect" variable. A number of prospective research studies have followed this approach. Their success has often been limited by factors outside of the study design that could not be controlled (e.g. changes in the structure of the organisation, product changes etc.) when the required study period is long (e.g. many months or years).

The second approach is to consider the change in the “exposure” variables that occur as a result of the ergonomic intervention. This approach relies on the acceptance of established “risk factors” for a number of musculoskeletal disorders, based on current “state of the art” research findings. Changes in exposure to these risk factors following interventions provides a different, but nevertheless valid, measure of the efficacy of these work system interventions. However, there are currently no suitable, practical and valid methods/tools available for health and safety practitioners.

The development and application of such a tool would have many advantages. Users would rapidly be able to demonstrate the extent to which ergonomic interventions at the workplace were effective in reducing risks to musculoskeletal injuries. The tool could also be used to advise on the measures that should be taken for the improvement of the workplace/tasks and the likely impact and potential cost benefit of a number of alternative interventions.

1.2 RESEARCH PROCEDURE

The project started in March 1996, with the following stages:

- Investigation of the potential users’ needs for the exposure tool, through, for example, ‘focus groups’, questionnaires, users’ design of the tool, and verbal protocol approach.
- Literature research for “the state of the art” concerning work-related musculoskeletal disorders and the “risk factors”.
- Research experts’ view about making the risk assessment.
- Critical studies of current techniques for assessing the exposure to work-related musculoskeletal risks.
- Construction of the prototype exposure assessment tool.
- Evaluation and improvement of the prototype tool based on experimental studies.
- Evaluation of the exposure tool in field studies.
2. INVESTIGATION OF THE USERS' NEEDS

User participation in the application of ergonomics is an important issue, and the user-centred approach has been advocated as an essential component in the design of the human-machine system (Norman and Draper, 1986, Kontogiannis and Embrey, 1997). In ergonomics analysis and design, user participation is considered to be the first stage of establishing the requirements for the system, the tasks and the users (Wilson and Rajan, 1995). In order to understand the needs of health and safety practitioners for a practical risk assessment tool, a series of studies were carried out using focus groups, questionnaire surveys, users' self design of the tool, and a verbal protocol approach. These will be described in detail in the following sections.

2.1 INVESTIGATION OF THE USERS' NEEDS THROUGH FOCUS GROUPS

2.1.1 Method

Meetings were held with a series of user focus groups ranging between four and eight people in each group. They comprised professionals and practitioners from industry who had responsibilities for health and safety. The meetings focused on the problems and difficulties they had with existing exposure assessment methods (e.g., HSE checklists), and their needs and/or recommendations for the new tool and its practical use. Care was taken to ensure that the evolution was guided by the user comments and not by research expectation.

2.1.2 Results of user focus groups

Some of the results obtained from the focus group studies have been reported elsewhere (Buckle and Li, 1996.) Further details concerning the problems with the use of the existing methods/tools encountered by the health and safety professionals, and their suggestions about the development of a new tool are given below.

Problems with the existing risk assessment methods:

The focus groups commented on the problems with existing methods for identifying exposures or risk factors relating to musculoskeletal disorders. They included:

Usability of the available methods:

- "Too much detailed paper work (such as filling in a form with many questions)."
- "Training is often needed for using an assessment method, but as the quality of training may vary, then so does the assessment result."
- "Users often do not have adequate scientific knowledge to carry out detailed task analysis, nor do they have the facilities or time to carry out this analysis."
- "A form (or method) which covers everything tends to be very difficult to answer. The results may be unreliable as some of the questions can be answered in the office instead of going to the factory."
- "Postures quantified in degrees are difficult to measure."

Time issues:

- "(Some available methods are) time consuming and labour intensive, therefore people are reluctant to use due to time constraints."
• "Time constraints with respect to the level of analysis required"

Suitability for the job:

• "The available methods do not always fit into a practical situation."
• "Many of them (the tools) are not task-specific, especially in the area of manual handling of animate loads."
• "The risk factors associated with manual handling are complex. Check lists are too simplistic and can be very subjective. They only provide a general indication of the risk."

Other issues:

• "With the available methods, it is sometimes difficult to interpret the assessment results or answers."
• "Too qualitative and subjective."
• "Difficulties in prioritising risk factors. Many checklists identify only presence or absence of risk factors. It is difficult to judge magnitude or significance of risk vs. other risk factors. For example load - how do we define ‘heavy’, ‘light’ etc. Interpretations may vary widely within a group of assessors."
• "Risk factors can sometimes be identified (with the available methods), but it is difficult to evaluate risk levels."
• "No method is available for the re-assessment (after intervention)."
• "The risk factors may vary for different individuals and for the same individual at different times, therefore making risk assessment a difficult job."
• "Difficult to implement recommendations or changes that are effective."
• "Each type of method has its uses and limits. Also, knowledge about or effort taken to learn the assessment technique."

Users' needs for a new tool as suggested by the focus groups:

• "Quick and easy to evaluate a problem and produce results."
• "Soft copy would be ideal for assessment recording."
• "Same form of rating scale for risk, preferably numeric would be useful as a means of convincing others there is a real problem in the workplace."
• "Quantitative checklist with specific criteria for different tasks."
• "The new system should have a broader basis, covering task, load, environment and individual."
• "Reliability and ease of use by the operator."
• "Ease of comprehension (of results), eg. Pictorial translation."
• "Comprehensive - all major risk factors covered."
• "Relatively easy to complete in about 10-20 minutes (5-10 min was also suggested)."
• "Proven in the workplace - tested for consistency and practicability."
• "Easy to extract information concerning key risk factors and some indications concerning priorities for action."
• "The new tool should have a sound scientific basis; it needs to be flexible to accommodate the numerous and complex tasks carried out by a variety of personnel in differing environments. The assessment tools need to have standardised measures; it needs to be 'user friendly'; clear baselines need to be easily established."
• "The tool needs to be very simple, short (e.g. one-to-two page A4 paper), but precise."
• "There may be a level of common sense to do the risk assessment."
2.2 INVESTIGATION OF USERS’ NEEDS BY QUESTIONNAIRE SURVEYS

2.2.1 Method

After the investigation of users' needs/comments through focus groups, a questionnaire was designed to study a wider range of health and safety practitioners. This sought their opinions about, for example, the use of existing risk assessment methods/tools, their experience with health and safety work, and their preferred format/choice for the tool. A total of 180-200 practitioners were surveyed. The participants represented occupational health and safety professionals from a wide range of the UK industrial and service sectors.

2.2.2 Results of the Exposure Tool Questionnaire survey

A total of 93 fully completed questionnaires were returned, accounting for 46.5-51.7% of the total questionnaires distributed. The relatively “low” return rate was in part due to the fact that a proportion of those surveyed had never made risk assessment and therefore felt little need to complete the questionnaire.

The respondents were from a wide range of occupations, including environmental health officers, occupational health managers/co-ordinators, nurses, occupational physiotherapists, safety engineers, HSE project managers, training co-ordinators, clinical ergonomics advisors, health & safety advisors/officers/engineers, hygiene managers/chemists, occupational hygienists, back care advisors/co-ordinators, risk assessment trainers, moving and handling advisors, site/general managers, ergonomists, risk assessors, care managers and health & ergonomics consultants.

Users’ needs for a new tool based on questionnaire survey

Information obtained from the questionnaire survey was helpful for the understanding of the current situation for practitioners regarding exposure assessment. Their preferences, problems and suggestions with regard to the use of risk assessment methods have been summarised under each item. The potential users’ needs for a new exposure tool as obtained from the questionnaire survey also reflect, to a large extent, the opinions of those in the focus groups. However, answers in the questionnaires provide more specific and detailed information than that in the previous “focus group” studies. Some of the major points are summarised below:

- User friendly, easy and quick to use.
- Have scores to measure the level of risks. (This will also be useful for convincing others there is a ‘real’ problem in the workplace).
- Applicable to a variety of work situations.
- Have introduction about how to use the method (or how to carry out assessment).
- To complete the assessment in 10-20 minutes.
- Have sound scientific basis.
- Broader spectrum and cover all aspects of the assessment.
- Involvement of operators (workers).
- Reliable.
2.3 UNDERSTANDING THE PRACTITIONERS' BEHAVIOUR WHEN MAKING RISK ASSESSMENTS AT THE WORKPLACE - A THINK ALOUD APPROACH

Summary

Researchers have used many methods in order to assess physical exposure to risk factors for work-related musculoskeletal disorders. However, the development of satisfactory tools for health and safety practitioners to use when assessing physical risks at the workplace still presents a challenge.

A study was carried out to investigate how practitioners make exposure assessments for three simulated tasks, (manual assembly (bolting), manual handling (lifting) and VDU work (word processing)), using a "think aloud" approach. The method and procedure of the study have been reported elsewhere (Buckle and Li, 1998a).

The study indicated that the practitioners preferred to use descriptive words rather than to define specific angles in posture assessment.

Some preliminary results also suggested that the practitioners assessed the general workplace and/or task factors both at the start and throughout the assessment procedure. They also paid more attention to the physical exposure of the back than the other parts of the body. The study showed that, although risk assessment is a complex process, patterns might exist with regard to the order of the observation or assessment. More details and the implication of the results are discussed in the paper, cited above. This study has provided a better understanding of the observers' behaviour and needs when making risk assessment in the workplace.
3. SCIENTIFIC FINDINGS CONCERNING RISK FACTORS FOR WORK-RELATED MUSCULOSKELETAL DISORDERS

3.1 INTRODUCTION

Work related musculoskeletal disorders (WMSDs) are a common health problem throughout the world and a major cause of disability (Kelsey and Golden, 1988; Hagberg et al., 1995). The term musculoskeletal disorders refers to conditions that involve the nerves, tendons, muscles, and supporting structures of the body. World Health Organisation (WHO) defines musculoskeletal work-related diseases as multifactorial where a number of risk factors (e.g., physical, work organisational, psychosocial, individual, and social-cultural) contribute significantly to their development (WHO 1985). The term work-related disorder covers both the terms work-related illness and work-related disease (Hagberg, 1996).

The epidemiologic evidence regarding the role of physical as well as psychosocial factors in the development of WMSDs has been reported in many resources, with one of the latest and perhaps the most comprehensive review being that from NIOSH (1997). There is substantial evidence that the major risk factors that should be eliminated or at least minimised are those related to the manual handling of materials, repetitive work, static work, segmental vibration, and poor psychosocial work environments.

“Exposure” refers to the external factors of work that produce internal doses (e.g. metabolic demands or tissue loads). The focus of the exposure assessment has been on the hands and wrists, elbows, shoulders, neck and back because most of the reported work-related injuries are to these body parts (Wick et al. 1996). In this chapter, it is not intended to repeat what has been reviewed in those published documents with respect to the “exposure-response relationships”, or the “strength of association” between “risk factors” and the WMSD outcomes as detailed information can be obtained from the published review and tables in NIOSH (1997). Instead, the main purpose of this section is to identify and summarise those “risk factors” that have been widely acknowledged to have causal effect on the development of WMSDs in the regions of the back, shoulder and arm, hand and wrist, and the neck. This will form a scientific basis for the development of the exposure tool for the present research project.

3.2 SUMMARY OF EPIDEMIOLOGICAL LITERATURE ON RISK FACTORS FOR WMSDS

Based on substantial epidemiologic research, evidences are obtained for the association between physical work factors and WMSDs, as summarised in Table 3-1.
<table>
<thead>
<tr>
<th>Body part</th>
<th>Risk factor</th>
<th>Strong evidence (++++)</th>
<th>Evidence (++)</th>
<th>Insufficient evidence (+/0)</th>
<th>Evidence of no effect (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck and Neck/shoulder</td>
<td>Repetition</td>
<td>✓</td>
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<td></td>
<td>Force</td>
<td>✓</td>
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<td></td>
<td>Posture</td>
<td>✓</td>
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<td></td>
<td>Vibration</td>
<td>✓</td>
<td></td>
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<tr>
<td>Shoulder</td>
<td>Posture</td>
<td>✓</td>
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<td>Force</td>
<td>✓</td>
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<td></td>
<td>Repetition</td>
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<td></td>
<td>Vibration</td>
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<td>Repetition</td>
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<td></td>
<td>Force</td>
<td>✓</td>
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<td></td>
<td>Posture</td>
<td>✓</td>
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<tr>
<td></td>
<td>Combination</td>
<td>✓</td>
<td></td>
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<tr>
<td>Hand/wrist</td>
<td>Carpal tunnel syndrome</td>
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<td>✓</td>
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<td></td>
<td>Force</td>
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<td>Posture</td>
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<td>Vibration</td>
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<td></td>
<td>Combination</td>
<td>✓</td>
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<td></td>
<td>Tendinitis</td>
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<td>Repetition</td>
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<td>Posture</td>
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<td></td>
<td>Combination</td>
<td>✓</td>
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<tr>
<td>Hand-arm vibration syndrome</td>
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<tr>
<td>Back</td>
<td>Lifting/forceful movement</td>
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<td>Awkward posture</td>
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<td>Heavy physical work</td>
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<td></td>
<td>Whole body vibration</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
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<tr>
<td></td>
<td>Static work posture</td>
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</table>
According to NIOSH (1997), strong evidence of work-relatedness indicates that "a causal relationship is shown to be very likely between intense or long-duration exposure to the specific risk factor(s) and WMSDs. A positive relationship between exposure to the specific risk factor and WMSD has been observed in studies in which chance, bias, and confounding factors could be ruled out with reasonable confidence in at least several studies."

Evidence of work-relatedness (+++) indicates that some convincing epidemiologic evidence shows "a causal relationship when the epidemiologic criteria of causality for intense or long-duration exposure to the specific risk factor(s) and WMSDs are used. A positive relationship has been found between exposure to the specific risk factor and WMSDs in studies in which chance, bias, and confounding factors are not the likely explanation."

Insufficient evidence of work-relatedness indicates that "the available studies are of insufficient number, quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of a causal association. Some studies suggest a relationship to specific risk factors, but chance, bias, or confounding may explain the association."

Evidence of no effect of work factors indicates that "adequate studies consistently show that the specific workplace risk factor(s) is not related to development of WMSDs.

In general, there is sufficient evidence to support a causal relationship between some physical work factors and WMSDs in some body parts. The risk of each exposure depends on a variety of factors such as force, repetition, and duration. Strong evidence exists for an association between physical task factors and WMSDs, particularly when there are high levels of exposure involved in the job (e.g., manual handling of heavy objects) and when the risk factors are presented in combined manner (e.g., tasks with high-force and high repetition of the hand/wrist and arms, or heavy load handled in awkward postures of the back).

There is increasing evidence that some psychosocial factors are related to the development of WMSDs. Despite the fact that the findings of the epidemiological studies are not entirely consistent, they suggest that perceptions of intensified workload, monotonous jobs, limited job control, low job clarity, and low social support are associated with various types of WMSDs.

Some individual factors are also found to be associated with a variety of WMSDs. There is little evidence to show, however, that these individual factors interact synergistically with physical factors (NIOSH, 1997). Potential difficulties with ergonomic intervention for these factors creates problems in using these factors in the work system risk assessments.

The combination and interactions of various risk factors is similarly difficult to quantify with regard to their influence on the magnitude of exposure level. It is thought prudent to consider the potential relationship between such combinations, albeit that assumptions are required.

It is therefore assumed that, where a risk factor can be 'described' or 'measured' in terms of different magnitude levels (e.g., high, medium and low), the combination of two (or more than two) 'high-level' risk factors can be regarded as having a higher level of exposure (with higher exposure score) than the combination of two 'low-level' risk factors (with relatively low exposure score).

For the purpose of making exposure assessment at the workplace for WMSD risks, an exposure tool based on this format of exposure quantification seems to be reasonably practical, providing that the same tool is used between different tasks, or before and after an ergonomic intervention (Li and Buckle, 1997c).
3.3 A CRITICAL REVIEW OF TECHNIQUES FOR ASSESSING THE EXPOSURE TO WORK-RELATED MUSCULOSKELETAL RISKS

Physical exposure to risks for potential work-related musculoskeletal injuries has been assessed with a variety of methods, including pen and paper based observation method, videotaping and computer aided analysis, direct or instrumental techniques, and approaches to self-report assessment. These were critically reviewed during the process of this research project (Li and Buckle, 1997b). The applications of these techniques in ergonomic and epidemiological studies were considered, and their advantages and shortcomings were highlighted. A strategy that considers both the ergonomics experts’ view and the practitioners’ needs for developing a practical exposure assessment tool was proposed.

3.4 PROBLEMS WITH CURRENT EXPOSURE ASSESSMENT METHODS – THE EXPERTS’ POINT OF VIEW

Problems with the use of current exposure assessment methods have been reported in detail elsewhere (Li and Buckle, 1997b). According to some research experts, suitable analytical methods are still not available for efficiently reducing and quantifying physical exposure (Radwin et al. 1994). Several observation methods for analysing postures and movements have been developed. However, they are time-consuming and labour intensive (Wiktorin et al. 1995).

Most exposure assessment methods/tools involve two (usually contradictory) qualities, sensitivity and generality. High generality in an observation method is usually compensated by low sensitivity. For example, OWAS (Karhu et al. 1977) has a wide range of use but the results can be low in detail; in contrast NIOSH (Waters et al. 1993) requires detailed information about specific parameters of the posture to give high sensitivity with respect to the defined indices, but no general information about the task. Hignett (1994) found that OWAS lacked sensitivity for nursing work involving non-repetitive tasks at multi-functional, heterogeneous workstations. Burdorf et al. (1992) concluded that some of the ‘best known’ direct observation methods, such as OWAS and posture targetting, lack precision, are less reproducible in dynamic work situation, are not continuous, and are subjected to intra-and inter-observer variability. Hagberg (1988) reviewed approximately ten published methods for the systematic observation of occupational musculoskeletal loads and found that none of these methods were widely accepted.

Nowadays, several computerised systems (mainly based on the OWAS) have been developed for making the risk assessment less demanding (eg. Kant et al. 1992; Long, 1992; Leskinen and Tonnes, 1994; Pinzke 1994). The bottleneck in both the manual and the computerised OWAS systems is their recording procedure. The systems require that an operator classify a work posture (among several classifications) and record it onto a form or through the computer keyboard. This has been experienced as a time consuming and tedious task (Pinzke 1996).

Information about physical and psychosocial job exposure may be obtained by questionnaire (eg. Kruorinka et al., 1987) or diary (Dallner et al. 1991). However, recent studies have indicated a too low validity (Burdorf and Laan, 1991) and reliability (Wiktorin et al. 1991) in relation to the needs for ergonomic interventions.

An overview of the literature shows that the most common way of classifying physical exposure in epidemiologic studies is by job title (Hagberg, 1988; Burdorf, 1992). However, this has many drawbacks - a job title may describe a variety of occupational tasks, for example,
the title 'machine operator' may represent a group of workers operating different types of machines with varying levels of exposure to different body parts. Furthermore, recent physiological studies have revealed that there may be a great variation in work posture motions between workers performing exactly the same occupational tasks (Kilbom and Persson, 1987; Hagner and Hagberg, 1989). Therefore, risk estimates in terms of job titles do not offer a practicable basis for ergonomic interventions (Winkel et al. 1995).

3.5 EXPERTS' VIEW ABOUT THE MAIN CRITERIA FOR EXPOSURE ASSESSMENT METHODS

Research experts' opinions can be found in many published sources. Some of the major points are summarised below:

- The method has to be cheap, easy to learn and use (Corlett, 1990; Sinclair, 1990).

- The method should be applicable to all sections of working life, and should take environmental and psychosocial aspects into consideration (Rohmert and Landau, 1983).

- The measurements have to be repeatable under re-described conditions, i.e. within the range of movements normally occurring in the actual work situation (Aarås and Strand, 1988).

- The recording equipment should not interfere with the movements being recorded (Aarås and Strand, 1988) and should not interfere with the worker's work (Wilson 1990; Kirwan and Ainsworth, 1992).

- The method should have high validity, reliability and sensitivity (Pinzke 1996).

- Assessment data should be readily coded for computer storage and analysis (Colombini et al, 1985).
4. CONSTRUCTION OF THE EXPOSURE ASSESSMENT TOOL

4.1 GENERAL CONSIDERATIONS

The construction of the exposure assessment method was based on the studies of the users' needs (Chapter 2) as well as up to date scientific findings with respect to "risk factors" for WMSDs. The focus of the assessment was on the physical exposure to the back, neck, shoulder and arms, and hands/wrists, as most of the reported WMSDs are to those body parts (sections 3.2&3.3). Improvements were made on the format and the contents of the tool throughout the course of this research, whenever new evidence was obtained from the experimental studies. It was considered that information about a task exposure should be provided by both the practitioners (observers) who conduct the risk assessment through observation, and the workers who have direct experience through the performance of the task. The exposure tool is attached as Appendix 1 to this report. The evidence for the construction of the exposure tool is presented below.

4.2 EXPOSURE ASSESSMENT BY THE PRACTITIONERS

4.2.1 Exposure assessment for the Back

**Back posture**

- When performing the task, is the back
  - A1: Almost neutral?
  - A2: Moderately flexed or twisted or side bent?
  - A3: Excessively flexed or twisted or side bent?

**Construction evidence:**

This is based on the findings that back WMSDs were associated with mild (21°-45°) and severe (>45°) back flexion, twist or lateral bend (>20°) (Punnett et al. 1991). A forward flexion of the back of less than 20° seems not to lead to a higher rate of LBP for workers with long periods of employment (Aarás, 1994).

The exposure magnitude is categorised into 3 levels for the assessment of back posture. This is based on consideration that postures of the back and arm may be difficult to classify into more than two to three categories by systematic expert observations (Kilborn, 1994a). Winkel et al. (1995) indicated that quantification of exposure by comprising more than 2-3 levels reduces the reliability and validity considerably as estimated by kappa statistics. Therefore, consideration is taken during the construction of the observers' assessment items (for all body parts), making sure that, if possible, the exposure are assessed within 2 to 3 levels.

The descriptive terms used, i.e., 'Almost neutral', 'Moderately flexed or twisted', 'Excessively flexed or twisted' are based on the understandings obtained from the investigation of users' needs using 'think aloud' method (section 2.4) and from the studies on sensitivities of each individual term based on fuzzy logic theory. In the guide on how to use the exposure tool, the posture categories (either bend or twist) are defined as the regions between 0-20°, 20°-60°
and >60°. This is based on consideration that a posture band between 20° and 45° seems to be too small for the observers to judge, and the current system used is in agreement with that adopted in RULA (McAtamney and Corlett, 1993).

**Back movement**

For manual handling tasks only:

- *Is the movement of the back*—
  - B1: Infrequently? (Around 3 times per minute or less)
  - B2: Frequently? (Around 8 times per minute)
  - B3: Very frequently? (Around 12 times per minute or more)

Other tasks:

- *Is the task performed in static postures most of the time? (either seated or standing)*
  - B4: No
  - B5: Yes

**Construction evidence:**

For manual handling tasks or heavy physical work, the movement of the back is categorised into 3 exposure levels, i.e., 'Infrequently' (eg. around 3 times/min or less), 'Frequently' (eg. 8 times/min) and 'Very frequently' (eg. 12 times/min or more). Original construction of this assessment item was partially based on OSHA Draft Standard (1995) in which the back movement was categorised as 1 to 5 times per minute and more than 5 times per minute.

Because epidemiological literature shows no sufficient evidence as to the 'safe' level of the back movement when performing manual handling tasks, for the construction of this exposure tool, back movement was assessed at 3 levels with suggested frequency of 1-5, 6-10 and >10 times per minute respectively. Further experimental studies (to be reported in sections 5.4 & 5.5) showed that the observers experienced difficulties distinguishing between the levels 'infrequent' and 'frequent', or between ‘frequent’ and ‘very frequent’, when the actual back movement was close to the boundaries (i.e., close to 5 or 10 times/min). Therefore, it was decided that the median value should be used to represent the corresponding frequent level.

For tasks other than manual handling, assessment is focused on the presence or absence of static posture load because this has been shown to be a risk factor for the development of LBP, especially when combined with long work duration. This assessment (B4/B5) should be considered together with the duration factor.

**Force/load and task duration**

Evidence about force/load and duration being risk factors associated with back WMDSs has been reviewed. Information about force/load and duration of the task for the exposure assessment of the back is obtained from the worker, and is covered later in this report.
4.2.2 Exposure assessment for the Shoulder/Arm

Shoulder posture

- **Is the task performed**
  - C1: At or below waist height?
  - C2: At about chest height?
  - C3: At or above shoulder height?

Construction evidence:
Working above shoulder height is widely recognised as a risk factor for shoulder WMSDs. Although there is no evidence to suggest, as far as the shoulder is concerned, that working below shoulder level (e.g. at chest height or waist height) is safe, it is considered that this classification for shoulder posture assessment is reasonably practical for assessing the change in exposure with the expectation of good sensitivity of the tool. For the reason of simplicity of the tool, reach distance is not included in the assessment items. Reach distance in itself has not been widely recognised as an independent risk factor for shoulder disorders although farther reach distance may result in more awkward postures of the back and shoulder. At this time, working height seems to be more important.

Repeated shoulder/arm movement

- **Is the arm movement repeated**
  - D1: Infrequently? (Some intermittent arm movement)
  - D2: Frequently? (Regular arm movement with some pauses)
  - D3: Very frequently? (Almost continuous arm movement)

Construction evidence:
Highly repetitive arm and shoulder movement increases the risk of shoulder tendon disorders (e.g. Bjelle et al., 1981), but the movement of the shoulder can be very different (in terms of the pattern and speed) from that of the hand/wrist, this is also true for the acceptable rates of movement for the two body parts. However, epidemiological studies have not provided sufficient information to define the frequency at which the repetitive shoulder movements should be regarded as ‘risky’, or how such terms as ‘frequent’ or ‘very frequent’ should be defined. It was decided therefore, that these terms be defined by the pattern or manner of the arm movement, rather than by the number of times the arm moves within a given period (e.g. 1 minute).

Force/load and task duration

Information about force/load and duration of the task for the exposure assessment of the shoulder/arm is obtained from the worker, and is considered later in this report.

4.2.3 Exposure assessment for the Wrist and Hand

Wrist/hand posture

- **Is the task performed**
  - E1: With almost a straight wrist?
  - E2: With a deviated or bent wrist position?
Construction evidence:
Sufficient evidence is now available indicating that awkward wrist/hand posture, especially in combination with force, repetition and duration, is a risk factor for the development of wrist disorders. The prevalence of wrist problems increases when the wrist is deviated beyond 15° or 20° from its ‘neutral’ or straight position. Therefore, this 20° wrist angle has been set as a boundary between a ‘good’ and ‘bad’ wrist posture, such as in RULA (McAtamney and Corlett, 1993). However, it is difficult for an observer to ‘measure’, through observation, whether the wrist is within or beyond 15° or 20° from its neutral position duration work. Therefore, it was decided that the wrist posture be assessed at two exposure levels on the current form, with further explanations being given in the ‘training guide’. The terms are chosen based on the investigation of users’ needs using ‘think aloud’ method and have been shown to be sensitive for describing relevant wrist postures among several linguistic descriptors, through the test of ‘fuzzy ratings’. Experimental studies also show that the current format of the wrist posture assessment can be regarded as a successful attempt.

Wrist/hand repetitive movement

<table>
<thead>
<tr>
<th>Is the task performed with similar repeated motion patterns?</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1: 10 times per minute or less?</td>
</tr>
<tr>
<td>F2: 11-20 times per minute?</td>
</tr>
<tr>
<td>F3: More than 20 times per minute?</td>
</tr>
</tbody>
</table>

Construction evidence:
Repetition has been widely recognised as a risk factor associated with CTS, especially when in combination with other task factors such as force and posture. High-repetitive tasks have been defined as those with work cycle time less than 30 seconds or with more than 50% of the cycle time involved in performing the same motion pattern. However, in many work situations, a work cycle may not exist, or if it does, work cycle time may vary periodicaly, which makes it difficult to assess within a limited observation period. Therefore, it has been suggested that the repetition should be assessed on the basis of movement rates (i.e., number of times repeating similar motion per minute), and the movement rate of 10 times per minute was regarded as being appropriate for the wrist (eg. Kilbom, 1997). For the purpose of simplicity and reality, the frequency of wrist movement is categorised into 3 levels (≤10, 11-20 and >20 times/min), these has been tested in laboratory situations and appear to be practically reliable.

Hand force exertion and task duration

Evidence about force and duration being risk factors associated with wrist/hand WMSDs has been presented. Information about hand force exertion and duration of the task for the exposure assessment of the wrist/hand is obtained from the worker, and is covered later in this report.

4.2.4 Exposure assessment for the Neck

Head/neck posture

<table>
<thead>
<tr>
<th>When performing the task, is the head/neck bent or twisted excessively?</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1: No</td>
</tr>
<tr>
<td>G2: Yes, occasionally</td>
</tr>
<tr>
<td>G3: Yes, continuously</td>
</tr>
</tbody>
</table>
Construction evidence:
There is strong evidence that awkward neck posture which is held for a prolonged period of time is a risk factor for neck or neck/shoulder WMSDs. Tilting the head/neck more than 30° greatly increases the neck extensor fatigue rates, but an angle of around 15° produced almost no subjective discomfort or EMG changes even after 6 hours work (Chaffin, 1973). A recent report indicated that time spent in neck flexion (with the critical angle of 15°) was significantly associated with neck and neck/shoulder disorders (Ohlsson et al., 1995). However, it is difficult for the observers to determine a specific neck angle through simple observation, and the ‘think aloud’ study shows that the practitioners prefer to use descriptive word(s) such as ‘excessively bent or twisted’ rather than using angular values.

Duration and visual demand of the task

Evidence about duration being a risk factor associated with neck or shoulder/neck WMSDs has been reviewed. Information about the duration and visual demand of the task for the exposure assessment of the neck is obtained from the worker, and is covered later in this report.

4.3 Exposure assessment by the workers

Force/load handled for the task

<table>
<thead>
<tr>
<th>What is the maximum weight handled in this task?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a1: Light (5 kg or less)</td>
</tr>
<tr>
<td>a2: Moderate (6 to 10 kg)</td>
</tr>
<tr>
<td>a3: Heavy (11 to 20 kg)</td>
</tr>
<tr>
<td>a4: Very heavy (More than 20 kg)</td>
</tr>
</tbody>
</table>

Construction evidence:
There is strong epidemiological evidence to show that heavy load or force is an important risk factor for the development of WMSDs especially in the regions of the low back, shoulder/arm and wrist/hand. It is considered that information about physical load/force should be obtained from the worker because it is the load handlers who knows how heavy the load is, particularly in the situation where the weight of the load is not easily visible.

It is not an easy topic to decide which load level can be regarded as ‘light’ or ‘heavy’. Literature research indicated that loads commonly handled in industry ranges between approximately 2.5 and 30 kg and LBP has been found to associate with the weight handling tasks around 5 kg (Punnett et al., 1991). Lifting up to or more than 10 kg at least once a day was related to increased back injuries (Venning et al., 1987). Increased LBP risks were also reported among people lifting at least 20 kg twice a day (Frymoyer et al., 1983). It has been suggested that 20 kg weight should represent the maximum acceptable weight of lift to male industrial workers for symmetrical lifting of asymmetrical loads (Mital, 1992). In risk assessment, the level of load/force has been assessed with a variety of classification methods, for example, 0-2 kg, 2-9(10) kg, >9(10) kg (McAtamney and Corlett, 1993; van der Beek et al., 1992); 1-5 kg, 6-15 kg, 16-45 kg, >45 kg (Fransson-Hall et al.- unpublished manuscript, cited in Kilbom 1994a); <10 kg, 10-20 kg, >20 kg (Karhu et al, 1977; Kivi and Mattila, 1991). In the present system, the load/force classification of <5 kg, 6-10 kg, 11-20 kg and >20 kg is used with the consideration that the system should not only be based on scientific findings (e.g. 20 kg or more is considered as very heavy), but also simple enough to assess. Besides, the load/force value will also be used for the exposure assessment of the shoulder/arm for manual handling tasks as well as for other tasks, 4 exposure levels are chosen to increase the assessment sensitivity.
Task duration

- How much time on average do you spend per day doing this task?
  
  b1: less than 2 hours.
b2: 2 to 4 hours.
b3: more than 4 hours.

Construction evidence:
It is evident that task duration is an important risk factor for WMSDs of the back, shoulder/arm, neck, and hand/wrist and this factor should be considered for the exposure assessment of all these body regions. Since the time available for the practitioners to assess a job or task can be very limited, it seems that the only way to obtain this information is to ask the worker.

Epidemiological studies have shown that when the daily exposure time exceeds 4 hours, the rates of WMSD complaints increase in the back, shoulder/neck particularly for seated tasks such as driving and VDU operation (e.g., Kelsey, 1975; Winkel and Westgaard, 1992). Performing standing or seated work more than 2 hours a day has also been considered as a risk level for the back although the 95% confidence intervals did not exceed one (Walsh et al., 1989). The present system is chosen because it will suit a wide range of practical tasks such as seated or standing, manual handling, repetitive or non-repetitive tasks, and the same assessment value will be used as a risk factor for the exposure to all the body parts assessed.

Hand force exertion

- When performing this task (single or double handed), what is the maximum force level exerted by one hand?
  
  c1: Low (Less than 1 kg)
c2: Medium (1 to 4 kg)
c3: High (More than 4 kg)

Construction evidence:
This assessment item is constructed for the evaluation of physical exposure to the hand/wrist, since in many work situations, the actual load handled can be different from the force exerted by hand. For example, in trolley pushing or pulling, the load on the trolley can be over 20 kg, but the actual hand force needed to push or pull the trolley may be much less (or even more), depending on the situation (whether it is a smooth floor or up a hill). Therefore, with respect to hand/wrist risk assessment, the force, which is a risk factor for the hand/wrist, should not be recorded directly from the load heaviness as is in the case of the back and shoulder assessment.

Epidemiological reports have suggested that, for the hand/wrist exposure, high-force jobs are those with estimated average hand force requirements of more than 4 kg and low-force jobs are those with hand force requirements below 1 kg (Silverstein et al., 1986). It is reasonable to say, therefore, that jobs with hand force between 1 kg and 4 kg can be regarded as 'medium-force.'
Worker Assessment of Vibration

- Do you experience any vibration during work?
  d1: Low (or no).
  d2: Medium
  d3: High

Construction evidence:
There is strong evidence that exposure to whole-body vibration is associated with LBP and exposure to hand/wrist vibration is associated with CTS and hand-arm vibration syndrome. But epidemiological studies show insufficient support for an association between exposure to vibration and the shoulder/arm or neck disorders. Despite the fact that vibration is a risk factor for the some body part, it is difficult to 'measure' the exposure to vibration through observation. At this time, the worker's subjective judgement seems to be the only way for the assessment of this type. Besides, evidence is insufficient as for how this factor should be considered in combination with other risk factors. The assessment result of vibration is therefore only taken as an additional reference factor, along with psychosocial factors.

Worker assessment of the visual demand of the task

- Is the visual demand of this task –
  e1: Low? (There is almost no need to view small details)
  e2: High? (There is a need to view some small details)

Construction evidence:
Visual demand is an essential factor indicating the head/neck postures adopted during work (Dainoff and Mark, 1987, Graf et al., 1991). Recent studies have shown that the level of visual task demands significantly influences the head/neck flexion angle (Li, 1996), the head/neck posture is also strongly associated with neck disorders. In making exposure assessment, neck posture angles can sometimes be difficult to assess, while it is easier for the worker to tell whether or not there is a strong visual demand involved in the task. Experimental tests have shown a high reliability of this assessment item among user groups (addressed later in this report.)

Worker assessment on psychosocial factors

- Do you have difficulty keeping up with this work?
  f1: Never.
  f2: Sometimes.
  f3: Often

- How stressful do you find this work?
  g1: Not at all
  g2: Low
  g3: Medium
  g4: High

Construction evidence:
It is evident that subjectively perceived workload is associated with a variety of WMSDs. However, mental workload cannot be easily measured and workload can mean different things to different people. i.e., workload is not merely a property of the task, but of the task, the
human and their interaction (Tulga and Sheridan, 1980). Although literature has suggested that no single psychosocial or work organisational factor is the predominant cause of WMSDs (Hales et al., 1994), based on the current knowledge, some of the psychological factors can still be assessed with this exposure tool.

Time pressure and machine-paced jobs have been found to significantly correlate with job dissatisfaction, fatigue and mental or physical health of the workers (Broadbent and Gath, 1981; Clegg et al., 1987; Khaleque and Hossain, 1993). This aspect is reflected in the first question as shown above. It was not thought appropriate to ask whether or not it was a "paced" task because the worker has to do the work and the machine cannot be stopped. Instead, by asking the question in this way (as shown in the box), it may cover the worker's ability to cope with the task and the time pressure.

Stress, as an individual psychological state, is related to how the person perceives and then experiences the work system. It may be able to reflect, to a large extent, the person's overall exposure to psychosocial risk factors. It has been suggested that "if the person tells you that he is loaded and effortful, then he is loaded and effortful whatever the behavioural and performance measures may show" (Moray et al., 1979). This is the basis for the formation of the second question. However, at this time, it is unclear what their functions are and how they may interact with other risk factors. Therefore, the psychosocial factors are taken as a 'common reference' in the exposure tool.

4.4 Further considerations

Although the exposure tool is developed at a simple level so that it can be used by 'naive' or 'inexperienced' users, (i.e., the users who have little or no knowledge in ergonomics and inexperienced in making exposure assessments at workplaces), it is considered that a proper training is still needed for the use of the tool. Weston and Haslam (1992) found that ergonomists were significantly better at analysing two trial tasks than non-ergonomists. Kemmlert (1997) stated that, "To be honest, reliability and validity tests (of an exposure tool) are actually testing the educational level of the observers." Therefore, a short and simple training package is attached to the tool (see Appendix 2), which explains the meaning of the terms or assessment items, and some points that may be helpful to the practitioners for making exposure assessments. It is assumed that the quality of the assessment (eg. accuracy and reliability) will depend on both the format of the tool itself and the training materials that come with the tool.

4.5 The exposure score system

There is no evidence at this stage to confirm how the exposures to different risk factors should be weighted with respect to their contribution to WMSDs. It is evident, however, that the risk factors should be considered in combination with each other, and the effect of the combined risk factors (on the rate of WMSDs, or other physical/mental responses) can be very different from the separate effects. Several epidemiological studies have indicated that the combination of two 'high-level' risk factors (eg. high-force & high-repetition) resulted in a higher magnitude of WMSD rate than that of two 'low-level' risk factors. On the basis of this principle, the present score system has been formulated. It is considered that, although at this time the pattern of combination between risk factors is still not fully understood, this will not influence the use of the tool as long as the same system is used for the assessment of different tasks, or before and after an ergonomic intervention within the same task. In addition, some practitioners have expressed their preferences about the use of a score system as this will give a relative reference level of exposure and a suggested 'action' level, if possible, for an ergonomic intervention. This will need to be formulated and tested through appropriate field studies.
5. EVALUATION OF THE EXPOSURE TOOL – EXPERIMENTAL STUDIES

5.1 A PILOT TEST OF THE EXPOSURE TOOL BY A PRACTITIONER GROUP

5.1.1 Introduction

One of the most important features of the proposed exposure tool is that it should be able to identify the change in physical exposure to musculoskeletal risks before and after the ergonomic intervention to reduce the musculoskeletal risks associated with the job.

Reliability and validity are interdependent concepts; a method cannot be valid if it is not reliable. Reliability is an index of the consistency of a measure and addresses the representation problem. Validity is defined as the extent to which a measuring instrument measures what it is intended to measure.

The reliability of a method may be tested in a variety of ways. Essentially it concerns the degree to which the method can be repeated with the same result. In other words, whether a similar result can be obtained by different observers when assessing the same event (inter-observer reliability), or by the same observer on repeated observations at a time interval (intra-observer reliability).

There is little reported evidence in the literature regarding the reliability or validity of exposure assessment methods. This has been confirmed not only by the authors of this report, but also by other researchers (eg. Stanton and Young, 1997). It has been argued that the lack of evidence is not due solely to the complexity or vagaries of what validity and reliability mean. Rather, it is likely to be due to the lack of motivation on behalf of the people who develop and use the methods to ensure they meet with the development criteria that have been set.

The International Standards Organisation (ISO) defines the usability of a tool or product as being dependent upon “… the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments”. (ISO DIS 9241-11). In this report, the term “usability” is used to cover the characteristics of the exposure tool with respect to its simplicity and user-friendliness. These can be tested through, for example, the feedback of users’ opinion about the tool, the time needed for making the risk assessment, and the requirement for training.

5.2 IMPROVEMENT OF THE PILOT EXPOSURE TOOL AND THE TEST OF THE FINAL PROTOTYPE TOOL

Based on the information obtained from the experimental studies as reported, the opinions of the tool users who have participated in the tests (both the practitioners and the research experts), the understandings from the “think aloud” studies, and the studies of the relationship between linguistic terms and the perceived posture and frequency of movement for various body parts with the application of fuzzy logic theory (Li and Buckle, 1998), the exposure tool was continuously improved through five iterations. A series of experiments was carried out in the laboratory to test the reliability and validity of the tool (Version 5.0), as reported below.
5.2.1 Test of the exposure tool V.5.0 for inter-observer reliability, sensitivity and measurement validity using SIMI 3D motion analysis system

5.2.1.1 Experimental design

The general objectives of the test

- To test the sensitivity of the exposure tool, i.e., to evaluate whether the tool is sensitive to the changes in exposure between, for example, “low level” exposure (A1-G1) and a “medium level” (A2-G2) or “high level” (A3-G3) exposure as defined in the exposure tool V.5.0.
- To test the inter-observer agreement for their assessments for each individual exposure aspect, such as body posture and frequency of hand/wrist, arm and back movement.
- To test the measurement validity (or accuracy) of the tool by comparing the observers’ assessment with the instrumental recordings, by using the SIMI 3-D motion/posture recording system.

Design of the experimental tasks

Simulated tasks were designed that could be performed with a “known” (or controlled) levels of physical exposure to certain parts of the body. The tasks were assessed using the draft tool to determine whether the tool could assess effectively the levels of exposure for these tasks. Two manual handling tasks were performed in a standing position, and two manual assembly tasks were performed in a seated position. Both types of tasks were designed to have different exposure levels.

Task 1-1: Object (weight) re-positioning task (at “low” level exposure)

Design aim: This task was designed particularly for testing the exposure assessment of the back and the shoulder/arm. The task was intended to be designed in such a way so that the subject would not need to bend or twist his/her back more than 20° from the ‘neutral position’, as defined in the exposure tool. The design of the task also maintained that the shoulder/arm posture and movement were within the “lower” level of exposure, i.e., the task is performed at or below waist height with straight legs.

The subject was required to lift a box from one position slightly to the left-hand side of the subject, and place it on to a bench that was directly in front of the subject 100 mm below waist height. The task was performed in a standing position, at a frequency of 5 times per minute (using an audible signal to control the speed). The weight of the box was 4 kg (which is within the “light” range as defined in the draft tool). The height, width, and depth of the box were 245x450x345 mm. The box had two handles placed symmetrically 225 mm above the base with a distance of 45 mm between the two handles. The subject lifted the box from one height level (i.e. starting between knee and waist height) to another, and then, after 11-11.5 seconds’ interval, moved the box back to its starting position.

The subject was required to maintain a similar work posture and movement if possible throughout the task, and the subject had a rest of 3 minutes between tasks.
It was difficult to predict the neck posture by task design for this type of dynamic task since the subject might bend or twist his/her neck to see the object which was placed at the waist level. However, it was hoped that the neck posture could still be compared with the assessment of the other task designed for a higher level of exposure to other body regions, (eg. back and shoulder/arm), as described below.

Task 1-2: Object re-positioning task (at "medium" or "high" exposure level)

In this task, the subject was required to pick up a box (as described above) from a ‘low’ location (i.e., handle at knee height) to a higher level location (i.e., handle at about chest height), at a frequency of 7-8 times per minute. The weight of the object was 8 kg (which was within the “moderate” weight level as defined in the tool). The task was designed in such a way so that the subject would need to bend his/her back by more than 20° but less than 60° when performing the task. Based on the task design, the posture and movement of the shoulder/arm (and hand/wrist if possible) were also maintained at a “medium” exposure level, i.e., the task was performed at about (or up to) chest height.

Again, the neck posture was not controlled for this task, but it was considered that the angular range of the head/neck movement and the maximum flexion or extension or rotation when doing this task might be comparable with those when performing task 1-1.

Task 2-1: Repetitive task with small hand/wrist movement (at “low” level exposure)

Design aim: this simulated task was designed so that the exposure levels for the subject’s shoulder/arm, hand/wrist, head/neck and the back were controlled within “known” ranges (as defined in the tool).

The task was performed seated as is normal for this type of tasks in the practical work environment. The table and the seat were adjusted so that the table surface was at the subject’s sitting elbow height. The subject was required to pick up a plastic pin from a box (positioned on the table surface, in front of the subject, at a distance of elbow-to-wrist length) and insert it into a vertical hole on a plastic block. The height, width and depth of the block was 44 x 110 x 75 mm, on top of the block 8 rows of holes were evenly located, with 12 holes in each row. Each hole was 6 mm in diameter and 40 mm deep. The block was placed on the table surface, in the sagittal plane of the subject, at the distance of elbow-to-finger tip length, (this was measured when the upper arm was vertical, by the side of the body, and the elbow angle was at 90°). The pin was 40 mm in length and cone shaped, with its end being connected to a column that is 10 mm in length and 7 mm in diameter (the total length of the pin was 50 mm). The subject inserted the pin into a hole, starting from the top-left one, moving horizontally to the next one, and then down to the next row. The task was performed using only the subject’s dominant hand at a frequency of 8-10 times per minute.

Task 2-2. Repetitive task with small hand/wrist movement (at “medium” level exposure)

The same task as described above in Task 2-1 was performed by the same subject but in this case the block was located further away. At shoulder-to-fingertip distance (measured when sitting upright with arm fully stretched forward) plus 50 mm (which is the pin length) in the sagittal plane of the subject, at the height of 100 mm above shoulder level (between shoulder height and eye height). To maintain the task distance and height, the position of the seat was fixed during the test. The task was performed one-handed by the subject using his preferred hand, at the frequency of 15-20 times per minute. The hole was facing the subject, with the
surface of the block slightly tilted to the back at an angle of about 5 degree to prevent the pins from dropping out of the holes.

To control the frequency of each task, an audible signal was presented to the subject through an earphone, at the pre-determined frequency for each task. These were checked from the video recordings to make sure that the subject was doing the task at the designed speed. The "observers" could not hear the signals during their assessment of the tasks.

The duration of the task

The duration of each task was set within 5-10 minutes so as to make sure that the 'observers' could complete their exposure assessment within that time. The subject was allowed to stop performing the task before the designated duration if all observers had completed the assessment for that task.

Subjects

One healthy subject (male, stature: 1720 mm; sitting height: 910 mm*, sitting eye height: 780 mm*, sitting shoulder height: 600 mm*, sitting elbow height: 200 mm*, shoulder-fingertip length: 725 mm, weight: 65 kg. Note: * these were measured from the seat surface) The subject was a member of the university, who was paid at a standard rate for the work) acted as the “task performers” undertaking the four tasks in a pre-determined random order and the same work was observed by all observers. Some practice was given so that the subject could perform the tasks in the same way for different observer groups.

Before the test, the subject answered a standard medical disclosure questionnaire to make sure that his health condition was suitable for participating in the experiment, and signed a consent form for the trials. The work was recorded by two cameras for further 3-D motion/posture analysis.

Observers

18 persons (health & safety practitioners, 5 males and 13 females) participated in the experiment acting as "observers" using the exposure tool to evaluate the simulated tasks. Their mean age was 41.3 years (SD=9.31, Range=27-58), the average time they worked in health and safety was 5.19 years (SD=3.88, Range=1-18). The observers were divided into five groups with 3 or 4 people in each group. Before starting the assessment, the observers received a 10 minutes’ standard training by reading through brief instructions on how to use the exposure tool. The ‘tool use instruction’ is attached to tool V.5.0 in Appendix 5.

5.2.1.2 Results

Inter-observer reliability calculated as percentage agreement (%)

The results for inter-observer reliability calculated as percentage agreements are shown in Table 5-1. These are expressed as the agreement between the ‘designed’ or ‘known’ exposure level of an assessment item and the observers’ own judgement of the same item. The inter-observer agreements expressed as kappa coefficients are given in Table 5-2.
### Table 5.1. Inter-observer agreement (percentage agreement) (n=18)

#### Task: Manual handling 8 kg

<table>
<thead>
<tr>
<th>Exposure level</th>
<th>Agreement with the designed exposure level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 Level 2 Level 3</td>
<td>Designed level</td>
</tr>
<tr>
<td>Back posture (A)</td>
<td>0.0% 88.9% 11.1%</td>
</tr>
<tr>
<td>Back movement (B)</td>
<td>27.8% 55.6% 16.6%</td>
</tr>
<tr>
<td>Shoulder posture (C)</td>
<td>61.1% 38.9% 0.0%</td>
</tr>
<tr>
<td>Arm movement (D)</td>
<td>5.5% 88.9% 5.5%</td>
</tr>
<tr>
<td>Wrist movement (E)</td>
<td>66.7% 27.8% 5.5%</td>
</tr>
<tr>
<td>Wrist posture (F)</td>
<td>33.3% 66.7% NA</td>
</tr>
<tr>
<td>Neck posture (G)</td>
<td>55.6% 38.9% 5.5%</td>
</tr>
</tbody>
</table>

#### Task: Manual handling 4 kg

<table>
<thead>
<tr>
<th>Exposure level</th>
<th>Agreement with the designed exposure level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 Level 2 Level 3</td>
<td>Designed level</td>
</tr>
<tr>
<td>Back posture (A)</td>
<td>50.0% 50.0% 0.0%</td>
</tr>
<tr>
<td>Back movement (B)</td>
<td>72.2% 27.8% 0.0%</td>
</tr>
<tr>
<td>Shoulder posture (C)</td>
<td>100.0% 0.0% 0.0%</td>
</tr>
<tr>
<td>Arm movement (D)</td>
<td>22.2% 77.8% 0.0%</td>
</tr>
<tr>
<td>Wrist movement (E)</td>
<td>94.4% 5.6% 0.0%</td>
</tr>
<tr>
<td>Wrist posture (F)</td>
<td>44.4% 55.6% 0.0%</td>
</tr>
<tr>
<td>Neck posture (G)</td>
<td>61.1% 27.8% 11.1%</td>
</tr>
</tbody>
</table>

#### Task: Manual assembly at table height (sitting elbow height)

<table>
<thead>
<tr>
<th>Exposure level</th>
<th>Agreement with the designed exposure level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 Level 2 Level 3</td>
<td>Designed level</td>
</tr>
<tr>
<td>Back posture (A)</td>
<td>100.0% 0.0% 0.0%</td>
</tr>
<tr>
<td>Back movement (B)</td>
<td>72.2% 22.2% 5.6%</td>
</tr>
<tr>
<td>Shoulder posture (C)</td>
<td>33.3% 66.7% 0.0%</td>
</tr>
<tr>
<td>Arm movement (D)</td>
<td>0.0% 94.4% 5.6%</td>
</tr>
<tr>
<td>Wrist movement (E)</td>
<td>72.2% 22.2% 5.6%</td>
</tr>
<tr>
<td>Wrist posture (F)</td>
<td>94.4% 5.6% 0.0%</td>
</tr>
<tr>
<td>Neck posture (G)</td>
<td>72.2% 5.6% 22.2%</td>
</tr>
</tbody>
</table>

#### Task: Manual assembly at or above shoulder height

<table>
<thead>
<tr>
<th>Exposure level</th>
<th>Agreement with the designed exposure level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 Level 2 Level 3</td>
<td>Designed level</td>
</tr>
<tr>
<td>Back posture (A)</td>
<td>22.2% 72.2% 5.6%</td>
</tr>
<tr>
<td>Back movement (B)</td>
<td>5.0% 5.0% 89.0%</td>
</tr>
<tr>
<td>Shoulder posture (C)</td>
<td>0.0% 11.1% 88.9%</td>
</tr>
<tr>
<td>Arm movement (D)</td>
<td>0.0% 11.1% 88.9%</td>
</tr>
<tr>
<td>Wrist movement (E)</td>
<td>0.0% 61.1% 38.9%</td>
</tr>
<tr>
<td>Wrist posture (F)</td>
<td>11.1% 88.9% 0.0%</td>
</tr>
<tr>
<td>Neck posture (G)</td>
<td>88.9% 11.1% 0.0%</td>
</tr>
</tbody>
</table>
Table 5-2 Kappa coefficients for inter-observer agreement
(18 observers observing 1 subject performing 4 tasks)

<table>
<thead>
<tr>
<th>Assessment items</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back posture</td>
<td>0.44</td>
</tr>
<tr>
<td>Back movement</td>
<td>0.32</td>
</tr>
<tr>
<td>Shoulder posture</td>
<td>0.54</td>
</tr>
<tr>
<td>Arm movement</td>
<td>0.52</td>
</tr>
<tr>
<td>Wrist movement</td>
<td>0.30</td>
</tr>
<tr>
<td>Wrist posture</td>
<td>0.34</td>
</tr>
<tr>
<td>Neck posture</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Sensitivity of the exposure tool V.5.0

According to the experimental design, each task was performed at two levels of exposure for one or more than one particular body part, as has been described in section 5.5.1.1 and also shown in Table 5-1. The percentage of observers who found change (or no change) in exposure for the two types of manual handling tasks and two types of seated repetitive manual tasks was given in Table 5-3.

Table 5-3. Percentage of observers who found the change (or no change) in exposure for the two types of tasks tested (n=18)

<table>
<thead>
<tr>
<th>Assessment items</th>
<th>Manual handling task</th>
<th>Seated manual assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observer assessment</td>
<td>Designed condition</td>
</tr>
<tr>
<td></td>
<td>Change</td>
<td>No change</td>
</tr>
<tr>
<td>Back posture (A)</td>
<td>55.6%</td>
<td>44.4%</td>
</tr>
<tr>
<td>Back movement (B)</td>
<td>55.6%</td>
<td>44.4%</td>
</tr>
<tr>
<td>Shoulder/arm posture (C)</td>
<td>44.4%</td>
<td>55.6%</td>
</tr>
<tr>
<td>Arm movement (D)</td>
<td>22.2%</td>
<td>77.8%</td>
</tr>
<tr>
<td>Hand/wrist movement (E)</td>
<td>27.8%</td>
<td>72.2%</td>
</tr>
<tr>
<td>Hand/wrist posture (F)</td>
<td>33.3%</td>
<td>66.7%</td>
</tr>
<tr>
<td>Neck posture (F)</td>
<td>38.9%</td>
<td>61.1%</td>
</tr>
</tbody>
</table>

Note: * SIMI analysis indicated that the subject’s back postures when performing both manual handling tasks were found at the same exposure level, i.e., back flexion between 20-60° from the vertical. NA: not available for design control.
Usability of the tool (V.5.0) – Time spent for making risk assessment

The time spent for each observer group to complete one exposure assessment was recorded and the results are summarised in table 5-4.

<table>
<thead>
<tr>
<th>Observer group</th>
<th>Manual handling 4 kg</th>
<th>Manual handling 8 kg</th>
<th>Manual assembly at elbow height</th>
<th>Manual assembly above shoulder height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>1'13&quot; (1.22min)</td>
<td>3'27&quot; (3.45min)</td>
<td>1'46&quot; (1.77min)</td>
<td>2'25&quot; (2.42min)</td>
</tr>
<tr>
<td>Group 2</td>
<td>3'36&quot; (3.6min)</td>
<td>3'18&quot; (3.30min)</td>
<td>2'06&quot; (2.10min)</td>
<td>1'55&quot; (1.92min)</td>
</tr>
<tr>
<td>Group 3</td>
<td>5'11&quot; (5.18min)</td>
<td>4'30&quot; (4.50min)</td>
<td>3'30&quot; (3.50min)</td>
<td>2'49&quot; (2.82min)</td>
</tr>
<tr>
<td>Group 4</td>
<td>2'30&quot; (2.5min)</td>
<td>3'12&quot; (3.20min)</td>
<td>2'08&quot; (2.13min)</td>
<td>1'34&quot; (1.57min)</td>
</tr>
<tr>
<td>Group 5</td>
<td>3'45&quot; (3.75min)</td>
<td>3'27&quot; (3.45min)</td>
<td>2'40&quot; (2.67min)</td>
<td>2'51&quot; (2.85min)</td>
</tr>
<tr>
<td>Group 6</td>
<td>1'40&quot; (1.67min)</td>
<td>1'29&quot; (1.48min)</td>
<td>1'35&quot; (1.58min)</td>
<td>1'30&quot; (1.50min)</td>
</tr>
</tbody>
</table>

Mean 2.99 min 3.23 min 2.29 min 2.18 min
SD 1.47 0.98 0.70 0.60
Range 1.22-5.18 1.48-4.50 1.58-3.50 1.50-2.85

Note: Actual back flexion 25-30 degrees.

Validity test of the tool V.5.0

3-D SIMI motion analysis system was used to obtain the ‘true’ values of the body postural angles when the subject was performing the four tasks and these were used to compare with the observers’ assessment using the exposure tool V.5.0 and to determine whether the tool measured what it was supposed to measure. The SIMI results are shown in Figures 5-1 to 5-8. Figure 5-9 shows a SIMI analysis frame with posture/movement results corresponding to the ‘real’ movement of the subject performing the task.

5.3 INTER-OBSERVER AGREEMENTS FOR THEIR EXPOSURE ASSESSMENTS

- Percentage agreement

Table 5-1 shows that there was up to 88.9% inter-observer agreement for their assessment on back posture (A) when the subject was handling the 8 kg box from about knee level to chest height. But their assessment on back movement (B) did not reach as a high level of agreement (55.6%) for the same task. This suggested that some of the observers were not sure whether the back movement of 7-9 times/min could be regarded as ‘very frequent’ (more than 10 times per minute) or ‘frequent’ (6-10 times per minute) or even ‘infrequent’ (5 times per minute or less). Since the box-handling task was performed at the frequency of 7-9 times per minute that was close to the boundary between the ‘frequent’ and ‘very frequent’ or between ‘infrequent’ and ‘frequent’, observers might find it difficult to judge the exposure level. The agreement on back movement was higher for the 4-kg box-handling task where the box was handled at the speed of 5 times per minute. The results raised the question about whether it is suitable to give a
range of movement frequency for the back as problems occur when the actual work frequency gets close to the boundary.

Agreement on shoulder posture (C) assessment was not high for the 8-kg box handling task (61.1%) but high for the 4 kg handling task (100%). This was possibly due to the fact that some observers were uncertain about the position of the box when the handle of the box was raised to chest height but the bottom of the box was still at about waist height. Therefore, when asked about whether the task is performed at the waist height or chest height, they may have found it difficult to judge the position of the object or the hand. More explanation is needed in the ‘tool use instruction’ to clarify this definition.

Although their agreement on arm movement (D) was comparatively high for both box handling tasks (88.9%- 8-kg box and 77.8%-4-kg box), the majority of observers regarded the frequencies of arm movement at either 7-9 times/min or 5 times/min as the same level - ‘frequent’. The results suggested that either the task frequencies were designed to be too close to each other, so that the observers could hardly distinguish the difference, or the definition of the descriptive terms such as ‘infrequently’, ‘frequently’ or ‘very frequently’ needs to be further explained or redefined in the tool.

Wrist posture and movement, and the neck posture could not be controlled for the two types of manual handling tasks therefore the agreements on these items were not expected to be high. However, the majority of observers were able to categorise the wrist movement into ‘low level’ (94.4%) when the subject was handling the object at the frequency of 5 times per minute. But when the frequency was increased up to 7-9 times per minute, the observers still tended to rate the work rate as at the ‘low level’ for the wrist (66.7%). Therefore, there appeared to be similar problems with regard to the ‘boundary effect’ for the wrist movement as has been discussed earlier for the arm.

Assessment agreements were relatively higher for the seated repetitive manual tasks than that for the standing manual handling tasks, especially for the back posture (72.2-100%) and movement (72.2-89%), arm movement (88.9-94.4%), wrist posture (88.9-94.4%), and neck posture (72.2-88.9%). But the agreement was not high for the shoulder posture for the ‘manual assembly at table height’ task (66.7%) as compared with ‘manual assembly at or above shoulder height’ (88.9%). A possible reason for this was that the table was actually set between the subject’s waist height and the chest height for the ‘manual assembly at table height’ task. Therefore some observers judged this as ‘level 1’ (at or below waist height) (33.3%) and some judged as ‘about chest height’ (66.7%). Assessment on wrist movement did not agree highly (61.1-72.2%), suggesting that a similar problem existed for the assessment of this item, as has been raised above. The result also raised the question of whether the wrist movement should be assessed at two instead of three levels of magnitude.

• **Kappa analysis**

Only some of the Kappa coefficient values shown in Table 5-2 can be taken for analysis, such as back and shoulder postures and movements, and arm movement because these were supposed to be controlled for the four experimental tasks. Other assessment items (such as wrist and neck postures) were not controlled or ‘known’ particularly for the manual handling tasks. Therefore the assessment tended to be 50-50% for that task and the kappa coefficients were expected to be low.

The overall assessments of the back posture, shoulder posture and arm movement were within the range of ‘moderate agreement’ (0.41-0.60). Considering the fact that the kappa analysis has eliminated the ‘chance effect’ as might have existed in the ‘percentage agreement’ results, the ‘moderate agreement’ may be considered as a reasonable or practically acceptable level;
especially for the inter-observer reliability for such a 'universal tool' like this, which is
designed for use in a wide range of work situations. Better reliability will be achieved if the
tool is further improved in the aspects that have been discussed previously.

5.4 ABILITY OF THE TOOL (V.5.0) TO DETECT CHANGE IN EXPOSURE

As is shown in Table 5-3, for the assessment of seated repetitive manual tasks, between 77.8%
and up to 83.3% of the observers were able to distinguish the change in exposure for almost all
assessment items tested, suggesting that the tool is sensitive to the change in exposure for this
type of tasks. But the tool (or the observers) could only judge the exposure changes in the arm
and hand/wrist movements between the two types of manual handling tasks tested (72.2-
77.8%), and the exposure changes in the shoulder and back postures and back movement were
not highly identified (44.4-55.6%). As has been mentioned earlier, this might be due to the
design of the tasks as well as the design of the tool itself. SIMI analysis has indicated that the
subject's back posture was maintained at the same level of exposure for both lifting tasks,
which means that the observers were right when they indicated that there had been 'no change'
in the back posture between the two tasks.

5.5 USABILITY OF THE TOOL V.5.0

Owing to the time constraints on the experiment, the observers were not asked to answer a
questionnaire about their opinion of the exposure tool. The average time spent by the observers
to complete each assessment was between 2.18 minutes and 3.23 minutes (Table 5-4), with
shorter times being spent on assessing the seated repetitive tasks than that for assessing the
standing manual handling tasks. Nevertheless, the results suggested that the observer's
assessment could be done within approximately 5 minutes for each of the four tasks tested.
This is quick enough to meet the "users' needs" as determined from the investigation of the
'users needs' through focus groups and a questionnaire survey, reported earlier.

It may be interesting to see that the time spent for assessing the manual handling tasks was
longer (with larger SDs) than the time spent for assessing the seated repetitive tasks (with
smaller SDs) (Table 5-4), suggesting that people found it more difficult to assess the
predominantly dynamic tasks than the mainly static tasks. This might also have explained why
the inter-observer agreements were relatively lower for these dynamic tasks, as can be seen
from Tables 5-1 and 5-2.

5.6 VALIDITY OF THE TOOL V.5.0

For the performance of Task 1-1 with 4-kg load, which was supposed to be designed as a "low-
level" exposure to the back and shoulder/arm, the back flexion should have been controlled
within 0-20° from the vertical. However, the SIMI analysis showed that the actual back flexion
of the subject was between 1.5°-26° from the vertical (or 88.5°-64° from the horizontal as
shown in Figure 5-4) during the performance of the task. This explains why the observers were
unable to categorise the back posture as whether within or beyond 20° from the vertical.
Therefore the inter-observer agreement was 50%-50% (Table 5-1). The result suggested that
the observers were right in terms of their assessment on the actual back posture with the current
exposure tool.

As is shown in Figure 5-2, for 'Task 1-2' (lifting and repositioning an 8-kg box), the 'true'
back flexion angle from the vertical was between 2.2° and 47° (about 87.8°-43° from
horizontal). According to the assessment item defined in the tool, the back posture in this case
should be regarded as 'moderately flexed' or <60° from the vertical (level 2). Table 5-1 shows
that a majority of observers (88.9%) estimated the back posture as level 2, which was in good
agreement with the SIMI recordings. Only 11.1% of the observers considered the back posture as level 3 ('excessively flexed' or >60°). The results indicated that if it was not for the 'wrong' design of one of the manual handling tasks (handling 4-kg box) (as a matter of fact, it was found difficult to control the movement of the subject during the task performance especially for such a small angular range (e.g. <20° back flexion), therefore, finding the 'true' postural values by using a more 'objective measurement' may be a practical way of validating the assessment tool.

The rotation of the back during the performance of the 4-kg box-handling task is shown in Figure 5-7(a). About 10°-15° back rotation was recorded for this task. However, the magnitude of back twisting was smaller than that of the back flexion, suggesting that the observers assessed the back posture for this task mainly based on back flexion. A similar result was found for the handling of the 8-kg box, in which back rotation was also within a relative small range of 12°-13° (Figure 5-7(b)).

Figure 5-3 shows that for the performance of the simulated manual assembly task at table height (Task 2-1), the subject's back flexion was within 6°-17° from the vertical (84°-73° from the horizontal), which is classified into exposure level 1 'almost neutral' by the tool. Back rotation was also within 10° (Figure 5-8(a)). Table 5-1 shows that all observers (100%) agreed with the SIMI recording and assessed the back posture for this task as level 1. While for the other repetitive manual assembly task (Task 2-2), SIMI analysis indicated the back flexion of 1° to 21° from the vertical (Figure 5-4), and back rotation angle was more than 25° (Figure 5-8(b)), which enters into the exposure level 2 (20°-60°) as defined by the tool. Over 72% observers assessed the back posture as level 2 (Table 5-1), although some observers (22.2%) still regarded the back exposure as level 1. This is understandable because the actual back flexion was very close to the 20° boundary.

As for the sensitivity of the tool, 77.8% of the observers agreed that there was a change in postural exposure to the back between the two types of seated repetitive manual assembly tasks (Table 5-3) which is true according to the SIMI analysis. For the reasons discussed above, it is not practical to expect the observers (or the tool) to find out the change in exposure between the two manual handling tasks because the back angle was found basically within the same range of movement. In general, for the back posture is concerned, the exposure tool appears to be practically reliable based on this experimental study.

For the assessment of shoulder/arm posture, "SIMI" indicated the upper arm angle relative to the torso of about 10°-40° for the 4-kg box handling task (Task 1-1) suggesting a low level exposure to the shoulder/arm (level 1) (Figure 5-1). All observers agreed with this result (100%) (Table 5-1). For the performance of the other manual handling task (Task 1-2, lifting 8-kg box), the 'real' angle between the upper arm and the torso was found to be about 12°-70.5° (Figure 5-2), suggesting a potential confusion as to whether the task should be considered as being performed 'at/above shoulder height' (level 1) or 'at about chest height' (level 2). Table 5-1 shows that the observers could not judge the shoulder posture with confidence for this task, the agreement being 61% for level 1 and 38.9% for level 2. Again, this was also largely due to the difficulties of controlling the subject's movement for the task as has been discussed earlier. The results have also suggested that the observers' were not 'wrong' when using this tool with respect to their assessment for the shoulder/arm postures. Further analysis with the SIMI system showed that the subject's hand position (maximum height) was slightly below the shoulder height when performing the manual handling task with the 8-kg box (Figure 5-5 (b)). This confirmed the observers' judgement on shoulder/arm postures for the box lifting and repositioning tasks.
Figures 5-3 and 5-4 both show that the arm-torso angles were above 20° but below 65° for the two repetitive manual assembly tasks, while some observers considered the shoulder/arm posture for one task (Task 2-1) as level 2 (66.7%). More people (88.9%) considered the other task (Task 2-2) as level 3 (Table 5-1). However, a conclusion cannot be drawn based on this SIMI analysis because the arm-torso angle did not show whether the task was performed above or below the shoulder height. Information about hand position is also needed. Further 3-D analysis of the video recordings in SIMI indicated that the hand position was indeed above the subject’s shoulder level for Task 2-2 (Figure 5-6, b)) and the hand/task position was somewhere between waist level and chest level for Task 2-1 (Figure 5-6 (a)). In general, there is no evidence to suggest that the exposure tool is not reliable for the assessment of these experimental tasks for shoulder/arm postures. On the contrary, the tool (or the observers) could detect the ‘correct’ exposure level due to ‘unexpected’ movements by the subject.

Due to some difficulties in analysing video recordings on SIMI, head/neck postures were only analysed for two repetitive manual assembly tasks. The results indicated the neck angle of 130.8°-143.3° for Task 2-1 and 130.3°-148.6° for Task 2-2 (Figures 5-3 and 5-4), suggesting the tilting of the head/neck of more than 30° for both tasks, which is defined as ‘excessively flexed or twisted’ by the tool. However, most of the observers answered ‘No’ to the question ‘is the head/neck bent or twisted excessively’ (72.2%-88.9%). At this point, it is not known which data set is ‘wrong’. It needs to be noted that, in order not to produce an additional influence on the observers, markers were not put onto the relevant body joints of the subject. Therefore the digitisation of the video recordings by SIMI was based on the estimation of one single analyst. Greater bias might exist with the SIMI results for neck postures as compared to those for the back and shoulder/arm because the ‘imaginary’ point on the head during the digitisation procedure changes in its relative position between the two cameras due to viewing angle changes. Further studies are needed with respect to the accuracy and reliability of the SIMI system for the evaluation of different types of movement and postures of different body parts.

In summary, this experimental study has revealed some positive and, to a lesser extent, negative aspects of the exposure tool V.5.0 concerning its reliability, sensitivity and usability. The assessment items including the back posture, shoulder/arm posture and movement appear to be practically acceptable; evidence about items for wrist/hand posture and movement, and for the neck posture was not sufficient because of the difficulties in task design and data analysis. However, it has shown promise for the static and repetitive tasks studied. Improvements are needed with respect to the ‘boundary effect’ between categories especially for the back and arm movement, as well as for the ‘tool use instructions’ about the relevant items. Intra-observer reliability was not tested in these experimental studies and will need to be studied further. In addition, the tool needs to be tested with a wider range of tasks for its inter/intra-observer reliability and for other functional characteristics.
Figure 5.2: Manual handling task - lifting and positioning a 8 kg box

Back flexion (angle measured from the horizontal)

Upper arm/shoulder flexion

Wrist angle
Back flexion (angle measured from the horizontal)

Upper arm/shoulder flexion

Head/neck flexion relative to the back

Wrist angle
Back flexion (angle measured from the horizontal)

Upper arm/shoulder flexion

Head/neck flexion relative to the back

Wrist angle
(a) Hand position relative to the shoulder when lifting and repositioning the 4-kg box

(b) Hand position relative to the shoulder when lifting and repositioning the 8-kg box
Figure 5.6 Hand position in manual handling tasks

(a) Hand position relative to the shoulder for working at table height

(b) Hand position relative to the shoulder for working at/above shoulder height
Figure 5.7 Back rotation for manual handling task

(a) Back rotation when handling the 4-kg box

(b) Back rotation when handling the 8-kg box
Figure 5.8 Back rotation for seated manual assembly tasks

(a) Back rotation for manual assembly at table height

31.69 ° shoulder right - shoulder left  YZ-plane: angle
22.32 ° hip right - hip left  YZ-plane: angle

(b) Back rotation for manual assembly at/above shoulder height

46.48 ° shoulder right - shoulder left  YZ-plane: angle
21.68 ° hip right - hip left  YZ-plane: angle
Figure 5.9 Use of SIMI
6. EVALUATION OF THE EXPOSURE TOOL IN THE WORKPLACE

Previous experimental studies carried out so far have been on the evaluation of the exposure tool (V.1.0-V.5.0) for its reliability and sensitivity for up to four types of simulated tasks. Owing to the time limit of the practitioners who took time off their work and participated in the tests, the number of test conditions had to be very limited as well as the number of subjects the practitioners could observe within the time. Although much useful information has been obtained from these experiments, and some improvements have been made based on these results, a requirement existed to consider the use of the tool in practice and in a variety of different jobs where many task elements cannot be controlled. Therefore, another set of experiments was conducted to test the tool V.5.0 for its inter- and intra-observer reliability with a wider range of industrial tasks.

6.1 TEST OF INTER-OBSERVER RELIABILITY

6.1.1 Tasks assessed

Eighteen different task recordings were selected from videotapes of jobs and tasks. The tasks included 'Repositioning of empty barrels', 'Bag handling and machine refilling', 'Trolley pushing', 'Packaging', 'Supermarket checkout operations', 'Work at assembly line', 'Manual handling of plastic containers', 'Repetitive task (seated)', 'Repetitive task (standing)', 'Product inspecting (standing)', 'Chicken processing', 'Forklift operation', 'Chicken packaging', 'Barrel rolling upwards', 'Bottle packing (seated)', 'Paper roll fitting', 'Bottle packing (standing)', and 'Brick making'.

The selection of the tasks was based on the consideration that the tasks should cover as wide a range of jobs as practically possible, including static and dynamic jobs, highly repetitive tasks with low force/load, less or non-repetitive jobs with heavy force/load, and tasks performed in seated and in standing positions. The videos were edited so that each task lasted for 3'30"-3'40". Based on the previous findings, this task duration was adequate for most observers to complete the assessment with the tool V.5.0. The order of the recorded tasks was arranged such that the task characteristics, such as dynamic or static, seated or standing, repetitive or non-repetitive, heavy force or light force, were different between the adjacent tasks. Since the original videos were not made for the purpose of such observational assessment, the recording quality varied among tasks (e.g. lighting condition, camera position in relation to the worker and to the relevant body parts etc.). These were also taken into consideration during the order arrangement of the tape. There was a 30-40 second interval between two recorded tasks to give the observers a short break after one assessment.

6.1.2 Observers

24 practitioners participated in the test acting as 'observers'. They all came from health and safety occupations such as training co-ordinator/risk assessor, physiotherapist, nurse lecturer, ergonomicist, manual handling advisor, back care advisor, safety engineer, trainer and assessor etc. Their mean age was 41.2 years (SD=9.2, Range=26-59). The average time they worked in occupational health and safety was 8.8 years (SD=7.3, Range=2-33), and average experience with risk assessment was 3.0 years (SD=2.6, Range=0-9).
6.1.3 Practitioners' assessment - Procedure

The practitioners (observers) were divided into five groups with four or five people in each group. The 18 recorded tasks were assessed by each group independently on a different day but each session was arranged at the same time during the day (13:00-14:00). Before watching the videos, the observers had 5-10 minutes going through a brief instruction - 'A guide to the use of the exposure tool' (Appendix 5) during which the asked or discussed questions about the terms defined in the exposure tool. After this, the tape was played and the observers made their assessments on each recorded job with the tool V.5.0. If any subject could not complete the assessment within the time given, the tape was re-wound and re-played to make sure all observers could finish their assessment for that job. During the observation and exposure assessment, the observers wrote down their comments on the advantages, disadvantages or problems of the exposure tool with respect to its use for a particular task, and their views about any possible problems with the recording of the tasks.

6.1.4 Experts' assessment - Procedure

Based on the practitioners' comments and difficulties they have experienced during the risk assessment of all 18 tasks, it was decided to repeat the study using experts. A group of 'research experts' was asked to review the 18 task recordings and rate each task for its suitability for making risk assessment with the items specified in the exposure tool V.5.0.

All 'experts' were researchers at the Robens Centre for Health Ergonomics, European Institute of Health and Medical Sciences, University of Surrey. They all had been teaching and/or researching in the field of ergonomics and/or epidemiology in relation to musculoskeletal disorders for a number of years (Mean=12.9, Median=11.75, SD=8.7, Range=4-25). Before starting the video, a brief explanation was made to the experts about what the practitioners had done with the tool and with the recorded tasks. The experts then spent approximately 10 minutes going through the exposure tool V.5.0 and the “Guide to the use of the exposure tool” to familiarise themselves with the assessment requirement of the tool. The experts were then asked to rate the suitability of each task for such risk assessment on a 10-point bipolar rating scale (1=EASY to 10=IMPOSSIBLE). Seven rating scales were presented on each page (one page for one task), including the scales for back posture and movement, shoulder/arm posture and movement, wrist/hand posture and movement, and the neck posture. The experts rated each task corresponding to the question that was printed on top of each page: “How confident are you to assess the posture and movement as specified on the Exposure Tool for this job?”

6.1.5 Results

The first two tasks rated were not included in the analysis as earlier studies had shown that learning effects were apparent.

Experts' confidence ratings of the recorded tasks

Under the consideration of research and/or teaching experience in the field of work-related musculoskeletal disorders, the ratings of 6 experts were used for analysis. The mean rating score was calculated for each of the 6 researchers (i.e., the mean score of 7 assessment items x 18 tasks) and based on this, overall mean rating values of the 6 people were obtained: Mean=2.73, (Median=2.8), SD=0.9, Range=1.5-4.2, low quartile=1.9, upper quartile=3.4.
The experts’ ratings about each of the 7 assessment items (i.e., back posture, back movement, shoulder/arm posture, shoulder/arm movement, wrist/hand posture, wrist/hand movement and neck posture) for each of the 18 tasks were further analysed. It was considered that a Mean Confidence Score (MCS) of 5 or more than 5 should be regarded as ‘low confidence’ and the corresponding assessment items should be excluded from the video assessment due to ‘poor quality’ or ‘inadequate viewing angle’ of the recordings, which made it too difficult to assess the body posture(s) or movement(s) concerned. The results showed that the MCS of the wrist/hand posture for the following tasks was beyond 5.0: task 1 (Repositioning of empty barrels, 5.33), task 6 (Work at assembly line, 6.50), task 7 (Manual handling of plastic containers, 5.17) and task 12 (Forklift operation, 6.17). The MCS of the wrist/hand movement was either at beyond 5.0 level for task 6 (5.17) and task 12 (5.00). Only one task was found to be beyond the MCS level of 5.0 for the assessment of neck posture (task 4-Packaging, score: 7.60). The MCSs for the back posture and movement, shoulder/arm posture and movement were all below 5.0.

Practitioners’ exposure assessment for the recorded tasks

For the evaluation of inter-observer reliability of the exposure tool V.5.0, Cohen’s Kappa coefficients were calculated for the assessments of the 24 practitioners assessing 18 recorded tasks. Considering the fact that previous experience level may influence the assessment result, the results of 18 practitioners (out of 24) with 1-7 year’s experience in risk assessment, and the results of 11 practitioners out of 24 with 4-7 years’ experience in making risk assessment were further analysed. Percentage agreement was also calculated for the observer groups with 1-7 years’ experience and 4-7 years’ experience respectively. The results are summarised in Table 6-1.

6.2 TEST OF INTRA-OBSERVER RELIABILITY

6.2.1 Observers

In order to test the intra-observer reliability of the exposure tool V.5.0, a test-retest was conducted with 8 practitioners assessed the same set of 18 recorded tasks twice in 3-week interval. The 8 practitioners who all participated in the previous experiment for inter-observer reliability test (described in section 6.1.2) assessed the 18 recorded tasks again with the same exposure tool after 3 weeks. Their average age was 41 years (Median=44, SD=12.81, Range=26-59), average experience with health and safety occupation was 7.63 years (Median=5.00, SD=6.30, Range=2-20), and average experience in making risk assessment at their work was 2.5 years (Median=0.50, SD=3.25, Range=0-7).

The 8 observers assessed the 18 recorded tasks in the same day as one group and the procedure was identical to that of their first assessment (described in section 6.1). The individual’s test-retest results were analysed by chi-square test as well as by Cohen’s Kappa. Spearman’s Correlation and percentage agreement were also calculated between the two sets of data. In order to test the possible influence of the observers’ experience in making risk assessment on the test-retest relationship, further analysis was performed with the data from 3 observers who had 5 to 7 years’ experience in risk assessment at their work.

6.2.2 Results

The experimental data were analysed in SPSS and the results are summarised in Table 6-2, together with the observers’ details.
Table 6-1. Inter-observer reliability on assessment items as specified in exposure tool v.5.0

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>24 observers</th>
<th>18 observers with 1-7 years’ experience in risk assessment</th>
<th>11 observers with 4-7 years’ experience in making risk assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>M=41.2 (Median=40.5) SD=9.16 Range=26-59</td>
<td>M=42.67 (Median=41.50) SD=7.02 Range=32-55</td>
<td>M=42.45 (Median=42.0) SD=6.01 Range=35-52</td>
<td></td>
</tr>
<tr>
<td>Experience with H &amp; S occupation</td>
<td>M=8.78 (Median=7.00) SD=7.33 Range=2-33</td>
<td>M= 9.29 (Median=8.00) SD=7.61 Range=2-33</td>
<td>M=9.30 (Median=10.0) SD=3.97 Range=3-15</td>
</tr>
<tr>
<td>Experience with risk assessment</td>
<td>M=3.00 (Median=2.0) SD=2.59 Range=0-7</td>
<td>M=3.88 (Median=4.50) SD=1.96 Range=1-7</td>
<td>M=5.27 (Median=5.0) SD=1.01 Range=4-7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Kappa</th>
<th>Kappa</th>
<th>Kappa</th>
<th>Overall percentage agreement (adjusted)*</th>
<th>Kappa</th>
<th>Kappa</th>
<th>Overall percentage agreement (adjusted)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tasks 1-18</td>
<td>Adjusted*</td>
<td>Tasks 1-18</td>
<td>Adjusted*</td>
<td>Tasks 1-18</td>
<td>Adjusted*</td>
<td>Tasks 1-18</td>
</tr>
<tr>
<td>Back posture</td>
<td>0.34</td>
<td>0.36</td>
<td>0.33</td>
<td>72.6%</td>
<td>0.38</td>
<td>0.41</td>
<td>74.8%</td>
</tr>
<tr>
<td>Back movement</td>
<td>0.21</td>
<td>0.17</td>
<td>0.17</td>
<td>71.2%</td>
<td>0.19</td>
<td>0.19</td>
<td>66.8%</td>
</tr>
<tr>
<td>Shoulder/arm posture</td>
<td>0.50</td>
<td>0.46</td>
<td>0.47</td>
<td>80.2%</td>
<td>0.47</td>
<td>0.50</td>
<td>78.4%</td>
</tr>
<tr>
<td>Shoulder/arm movement</td>
<td>0.33</td>
<td>0.34</td>
<td>0.38</td>
<td>79.3%</td>
<td>0.30</td>
<td>0.35</td>
<td>78.2%</td>
</tr>
<tr>
<td>Wrist/hand posture</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>78.8%</td>
<td>-</td>
<td>-</td>
<td>78.3%</td>
</tr>
<tr>
<td>Wrist/hand movement</td>
<td>0.34</td>
<td>0.34</td>
<td>0.42</td>
<td>76.4%</td>
<td>0.29</td>
<td>0.42</td>
<td>72.7%</td>
</tr>
<tr>
<td>Neck posture</td>
<td>0.20</td>
<td>0.13</td>
<td>0.20</td>
<td>64.7%</td>
<td>0.25</td>
<td>0.25</td>
<td>69.1%</td>
</tr>
</tbody>
</table>

Note: * Based on "Experts’ confidence ratings" for exposure assessment (n=6, test conducted on 16/1/1998).
Table 6-2. Intra-observer reliability on assessment items as specified in exposure tool v.5.0
(Experiments conducted between Nov. and Dec. 1997; up to 8 observers assessing 18 recorded tasks in 3-week interval)

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>8 observers with 0-7 years’ experience in making risk assessment at work*</th>
<th>3 observers with 5-7 years’ experience in making risk assessment at work*</th>
</tr>
</thead>
<tbody>
<tr>
<td>M=41 (Median=44) SD=12.81 Range=26-59</td>
<td>M=46 (Median=46) SD=4 Range=42-50</td>
<td></td>
</tr>
<tr>
<td>Experience with H &amp; S occupation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M=7.63 (Median=5.0) SD=6.30 Range=2-20</td>
<td>M=8.67 (Median=10.0) SD=5.13 Range=3-13</td>
<td></td>
</tr>
<tr>
<td>Experience with risk assessment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M=2.5 (Median=0.5) SD=3.25 Range=0-7</td>
<td>M=6.33 (Median=7.0) SD=1.15 Range=5-7</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Chi-square Sig. level</th>
<th>Kappa</th>
<th>Spearman’s Correlation</th>
<th>Overall % agreement</th>
<th>Chi-square Sig. level</th>
<th>Kappa</th>
<th>Spearman’s Correlation</th>
<th>Overall % agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back posture</td>
<td>p≤0.000001</td>
<td>0.52</td>
<td>0.66**</td>
<td>73.4%</td>
<td>p≤0.000001</td>
<td>0.53</td>
<td>0.62**</td>
<td>75.0%</td>
</tr>
<tr>
<td>Back movement</td>
<td>p≤0.000001</td>
<td>0.50</td>
<td>0.66**</td>
<td>76.0%</td>
<td>p≤0.00003</td>
<td>0.39</td>
<td>0.65**</td>
<td>69.6%</td>
</tr>
<tr>
<td>Shoulder/arm posture</td>
<td>p≤0.000001</td>
<td>0.50</td>
<td>0.62**</td>
<td>69.5%</td>
<td>p≤0.00001</td>
<td>0.49</td>
<td>0.56**</td>
<td>68.8%</td>
</tr>
<tr>
<td>Shoulder/arm movement</td>
<td>p≤0.000001</td>
<td>0.53</td>
<td>0.64**</td>
<td>74.2%</td>
<td>p≤0.00025</td>
<td>0.49</td>
<td>0.57**</td>
<td>72.9%</td>
</tr>
<tr>
<td>Wrist/hand posture</td>
<td>p≤0.000001</td>
<td>0.45</td>
<td>0.45**</td>
<td>76.7%</td>
<td>p≤0.005</td>
<td>0.53</td>
<td>0.53**</td>
<td>84.6%</td>
</tr>
<tr>
<td>Wrist/hand movement</td>
<td>p≤0.000001</td>
<td>0.50</td>
<td>0.69**</td>
<td>67.9%</td>
<td>p≤0.00002</td>
<td>0.47</td>
<td>0.64**</td>
<td>64.3%</td>
</tr>
<tr>
<td>Neck posture</td>
<td>p≤0.000001</td>
<td>0.48</td>
<td>0.58**</td>
<td>66.7%</td>
<td>p≤0.05</td>
<td>0.32</td>
<td>0.47**</td>
<td>59.5%</td>
</tr>
</tbody>
</table>

Note:  *: Based on “Experts’ confidence ratings” for exposure assessment (n=6, test conducted on 16/1/1998).

**: Statistically significant at p≤0.001 level.
6.3 DISCUSSION

6.3.1 Inter-observer reliability of the exposure tool V.5.0

The test results for the inter-observer reliability of the exposure tool are shown in Table 6-1. When considering the assessment results of all 24 observers assessing all 18 tasks, their agreement on the assessment items were generally low as evaluated by kappa analysis, ranging between K=0.20-0.21 (for neck posture and back movement) and K=0.33-0.34 (back posture, shoulder/arm and wrist/hand movement). According to Landis and Koch (1977), the strength of agreement for all these assessment items can be regarded as “fair agreement” (K=0.21-0.40; the strength level of agreement are shown in Table 5-4). The 24 practitioners’ assessment on shoulder/arm posture resulted in a higher kappa value (K=0.50) suggesting a “moderate agreement” among the observers.

The assessments made by 18 practitioners out of 24 with 1-7 years’ work experience in risk assessment showed a slight improvement in their agreement for shoulder/arm and wrist/hand movement as compared to the results from 24 observers, but not so for other items, and the agreement strength was basically maintained at the same level, or even slightly lower for the shoulder/arm posture and back movement. As for the percentage agreement, these all reached above 71% apart from the assessment on neck posture (64.7%).

Further analysis of the experimental results from 11 observers who had 4-7 years’ experience in making risk assessment at their work showed some improvements in kappa values particularly for the back posture, shoulder/arm posture and wrist/hand movement, resulting in “moderate agreement” for these items (K=0.41-0.60 for ‘moderate’). But the agreement on shoulder/arm movement and neck posture was still not high, keeping at the “fair” level. Problems existed with the assessment of back movement (K=0.19-0.21, “slight” to “fair” agreement), which suggested that further improvements are needed in the tool especially for this assessment item. Inter-observer agreement on neck posture assessment was not high (K=0.25), this was not surprising because many researchers have encountered the similar problems before (Keibom, 1994a).

With respect to the wrist/hand posture evaluation, despite a high percentage agreement, the kappa value turned out to be very low, closing to 0, which means that, in such situations as several observers assessing one item (here wrist/hand posture) within two categories, even though a majority of people assess the item into the same category, there is not enough variation between the assessments therefore kappa analysis is not suitable for this type of evaluation. These results are in agreement with studies reported by Wiktorni et al. (1991). In this case, the wrist/hand posture has to be estimated by other evaluation method, such as percentage agreement. Alternatively, observations should be made on jobs among them, some are performed with an almost straight wrist/hand, and some are performed with bent or deviated wrist so that the observers will categorise the wrist posture into different levels. In the tasks used for the present study, however, most of them were performed with awkward wrist postures, (together of course with other obvious risk factor, that was perhaps why the films were made by this research group earlier for ergonomic investigations of the jobs), therefore the assessments were mainly in the same ‘cell’, making no sense for using kappa method.

For the reliability evaluation using percentage agreement, most of the assessment aspects were above 72-73% (for wrist/hand movement), with the agreement for back posture being about 75%, shoulder/arm posture, shoulder/arm movement and wrist/hand posture being over 78%. The agreement on neck posture was just below 70% (69.1%), but the agreement on back movement was still not high (66.8%). According to Baty et al. (1986), inter-observer agreement value of 75% can be regarded as acceptable (although this figure seems to be based on pragmatic criteria.
only.) Nevertheless, present studies show that the exposure tool meets the basic requirement of its inter-observer reliability.

In addition, it needs to be understood that assessing the recorded tasks can be very different from assessing the real ones, especially with those used for the present tests – the tasks were not recorded for the purpose of making such risk assessment and they were recorded from either a single viewing angle or from far distance. Taking these into consideration, the results obtained so far should be regarded as quite good. Further studies are needed for the assessment of practical tasks using the exposure tool.

6.3.2 Intra-observer reliability of the exposure tool V.5.0

The test results for the intra-observer reliability of the exposure tool are shown in Table 6-2. The results indicated that, among the eight practitioners who repeated the same assessment in three-week interval, the intra-observer agreements (or test-retest reliability) were all reached the level of 'moderate agreement' (K=0.45-0.53). The first vs. second test agreements were highly statistically significant with chi-square analysis (p<0.00001) for all seven assessment items, as well as the test of Spearman’s correlation (p<0.001). Percentage agreements were close or above 75% for the assessment of back posture (73.4%), back movement (76.0%), shoulder/arm movement (74.2%) and wrist/hand posture (76.7%); agreement on wrist/hand movement, neck and shoulder/arm postures were slightly below 70%. It is argued that, however, the percentage agreement involves more chance effect than other tests used here and can only be considered as a reference.

When the test-retest data were further analysed, i.e., data obtained from 3 observers (out of 8) who had 5-7 years’ experience in making risk assessment at their work, the intra-observer agreements were generally remained at the same level according to kappa analysis for most of the assessment items apart from the neck posture, which dropped from 0.48 to 0.32. The test-retest agreements were still statistically significant for all seven items with chi-square tests as well as Spearman’s correlation tests although the significance levels were reduced with some items as compared with the results of the eight observers. There is a slight increase or decrease in the values of percentage agreement for the 3 observers as compared with 8 observers, with respect to their test-retest agreement on the seven assessment items. However, the difference was not great between the two observer groups.

Summary

The studies suggest that the intra-observer reliability of the exposure tool is reasonably high and practically acceptable for the purpose of exposure assessment at current stage. It is also suggested that people with or without previous experience in making exposure assessment in their jobs are able to reach an assessment agreement at more or less a similar level. This is encouraging because the exposure tool is mainly developed for non-skillful observers. However, it is still not understood why some more ‘experienced’ observers can achieve a higher as well as a lower level of agreement towards different assessment items as compared with the whole observer group. The term ‘experience’ may mean different thing for different people. In the tests, this information was obtained through an questionnaire with a question “how many years experience do you have in making risk assessment in the workplace?” People with same experience level (e.g., ‘3 years’) may not necessarily have the same level of skill in making this type of risk assessment, and they may be better in judging some type of exposures (eg. back posture) than those less experienced observers, but may not necessarily be better in assessing other items (eg. back or shoulder/arm movement). It is anticipated that experience and training can improve the assessment reliability, but questions remain as to how much training is needed and what type of training should be given, for the practical use of the exposure tool.
7. EVALUATION OF THE EXPOSURE TOOL IN FIELD STUDIES

After being tested in laboratory situation with a number of simulated tasks, the exposure tool (V.5.0) was further improved in some aspects such as its layout and wording. Several field studies were carried out to test the sensitivity, suitability, reliability and validity of the tool for a variety of practical tasks. These are reported in the following sections.

7.1 EXPOSURE ASSESSMENT FOR "STONE PITCHING" TASKS

7.1.1 Tasks

The assessment was conducted in two coastal work sites (here named “work site A” and “work site B”) (approximately 25 miles away from each other.) The job requires the laying of stones on the sea/river bank to protect the bank from erosion by waves. The job consisted of several tasks, such as moving/handling stones from the top of the bank to the lower level, reshaping the stone with a hammer (7 lb. or approximately 3.2 kg in weight) when necessary, digging clay soil from the bank base using a square shovel, placing and adjusting the stone in position, and tamping down the stone into the clay bed using a wooden tamper. The tasks are not necessarily performed in the same order but they form the basic task elements for the job.

The size and weight of the stones vary, normally between 10-20 kg at work site A (but more than 20 kg stones can be found on some occasions), and most stones are over 20 kg at work site B. The slope of the bank at work site 1 is not as steep as at work site 2.

7.1.2 Subjects and assessment procedure

There were 5 workers at work site A and 4 workers at work site B (all males), performing similar type of stone pitching tasks as described above. All nine workers’ "exposures" for each task were assessed by one practitioner using the exposure tool (V.5.0). The practitioner works as a ‘Health, Safety and Training Consultant’ with 10 years’ experience in his job. The average age of the 5 people working at site A was 54.2 (SD=3.03; Range=50-57) and their average time in the job was 25.4 years (SD=7.02; Range=19-33). The average age of the 4 people working at site B was 35.5 (SD=3.52; Range=27-44) and their average time in the job was 3.9 years (SD=7.40; Range=0.2-15).

The practitioner observed each worker performing the three or four types of tasks and assessed each task using the exposure tool. The tasks were also recorded from a number of angles, on to video, by the researcher. Because of differences in the work situations between the two sites, some tasks regularly performed at work site A were seldom observed at work site B. For example, workers at site B were not seen, during the time of the site visit, to dig clay soil with shovel, nor were they seen to tamp down the stone into the clay bed using a wooden tamper, (although the tools were seen at the work site.) When asked, the workers stated that the stones were too big to be tamped down with the wooden tamper. In assessing the tasks in work site B, the practitioner decided that the stone handling and reshaping task could be further divided into ‘selecting and handling stones’ and ‘placing and reshaping stones’.

7.1.3 Results of exposure assessment

The exposure scores of each body part for the stone pitching job are given in Table 7-1. The results show that job exposure at work site B is higher than that at work site A for the stone
handling tasks Exposure level to each individual slightly varied for each assessment item, but the magnitude of exposure maintained within a similar level range for the same task.

Table 7-1. Exposure scores for the 'stone pitching' tasks of the two work sites (N=9)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Work site A</th>
<th></th>
<th></th>
<th></th>
<th>Work site B</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Back</td>
<td>42</td>
<td>42</td>
<td>-</td>
<td>30</td>
<td>30</td>
<td>48</td>
<td>48</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>Shoul/arm</td>
<td>38</td>
<td>38</td>
<td>-</td>
<td>26</td>
<td>22</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Wrist/hand</td>
<td>42</td>
<td>36</td>
<td>-</td>
<td>30</td>
<td>22</td>
<td>38</td>
<td>34</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Neck</td>
<td>18</td>
<td>16</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>16</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Other</td>
<td>22</td>
<td>17</td>
<td>-</td>
<td>17</td>
<td>17</td>
<td>22</td>
<td>17</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Stone handling and reshaping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digging clay soil with shovel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>36</td>
<td>-</td>
<td>36</td>
<td>36</td>
<td>26</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Shoul/arm</td>
<td>28</td>
<td>-</td>
<td>32</td>
<td>32</td>
<td>22</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Wrist/hand</td>
<td>34</td>
<td>-</td>
<td>26</td>
<td>22</td>
<td>22</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>42</td>
</tr>
<tr>
<td>Neck</td>
<td>16</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Other</td>
<td>17</td>
<td>-</td>
<td>22</td>
<td>17</td>
<td>17</td>
<td>34</td>
<td>17</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>Placeing and reshaping stones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>32</td>
<td>30</td>
<td>-</td>
<td>24</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoul/arm</td>
<td>28</td>
<td>22</td>
<td>-</td>
<td>16</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist/hand</td>
<td>28</td>
<td>22</td>
<td>-</td>
<td>22</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>14</td>
<td>10</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>17</td>
<td>17</td>
<td>-</td>
<td>17</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.1.4 Validity test

To test the validity of the exposure tool, i.e., to see whether it 'measures' what is supposed to be measured, video recordings were analysed using 'slow motion' and/or 'freeze frame' technique. Body angles of each individuals were measured from the television screen at the time when the relevant body part was thought to be most heavily loaded, based on the definitions/instructions in the exposure tool. Repetitive movements of the back, shoulder/arm and wrist/hand were also compared with video data. The results of the video analysis were then compared with the assessment results of the practitioner using the exposure tool. The same approach was adopted for the field studies, and the overall results are summarised later in this report.

7.2 EXPOSURE ASSESSMENT FOR LABORATORY WORK

This field study was carried out to assess the job exposure of a group of researchers working in a biological laboratory. Their job is to investigate water quality in rivers through the study of "macro-invertebrates".

Macro-invertebrates are the small animals that inhabit the sediments of rivers. They include insect larvae such as those of mayflies and caddis flies, together with snails, shrimps, worms and many others. These organisms provide information about the water quality in a river as they are unable to move very far and must therefore respond to everything contained in the water, including pollutants.
which occur only infrequently or at very low levels and which may easily be missed by normal chemical sampling.

7.2.1 Tasks

The tasks involved in the laboratory work include: collecting samples from river, washing and filtering the samples, sorting sample to provide a complete list of the 'taxa' found, and analysing sample using a microscope. Apart from the first task, i.e., collecting samples the from river, the rest of the tasks are performed in a laboratory environment. During the site visit, there were seven researchers working in the laboratory, and their job duties were almost identical: washing and filtering a sample, which takes about 30 minutes or less each day, sorting the sample, which takes more than four hours per day, and analysing samples using a microscope, which takes less than two hours per day. Sorting samples is the main task in their daily work during which the researchers maintain a static sitting position with flexed head/neck posture and elevated shoulder/arm for long periods, searching among the mixture of small animals and water plants (these are all similar both in colour and in size, ranging from less than 1 mm to about 3-4 mm). These workers have complained of frequent stiff necks or neck/shoulder pains and eyestrain and discomfort.

Four of the seven researchers (three females and one male) were assessed when performing different tasks, i.e., 2 performed the 'sorting task', 1 performed the 'microscope operation' and 1 performed the 'sample washing' task. The assessment was conducted by the same practitioner as described in section 7.1. The tasks were video recorded from different positions for further video analysis.

7.2.3 Results

The exposure scores for each of the three tasks observed are given in Table 7-2.

<table>
<thead>
<tr>
<th>Task</th>
<th>Exposure scores for each assessment item</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Back</td>
</tr>
<tr>
<td>Wash sample</td>
<td>18</td>
</tr>
<tr>
<td>Sort sample</td>
<td>23</td>
</tr>
<tr>
<td>Subject 1</td>
<td>22</td>
</tr>
<tr>
<td>Subject 2</td>
<td>10</td>
</tr>
<tr>
<td>Microscope operation</td>
<td>10</td>
</tr>
</tbody>
</table>

The assessment showed that 'sorting the sample' is the most stressful task in the job, and this was confirmed by the researchers' opinions about the job and their major musculoskeletal complaints for the performance of this task.

For the 'sorting sample' task, subject 2 had a slightly higher exposure score than subject 1. When asked for personal opinions about their body discomfort, after the assessments were conducted, it was found that subject 2 complained more about the eye strain than subject 1. Further analysis from the video also showed that subject 2 was seen to rub her eyes from time to time. She was also found to support her head with one hand during work, indicating a probable attempt to reduce discomfort or fatigue in the neck and shoulder regions.
7.3 EXPOSURE ASSESSMENT FOR VDU OPERATION AND GENERAL OFFICE WORK

7.3.1 Tasks

This assessment was conducted in the office environment with two female office workers mainly working at VDU for word processing or data entry, and one 'secretary to the manager' (female) using VDU as well as performing other office tasks. The assessments were made by the same practitioner as described in sections 7.1 and 7.2. The tasks were recorded for further video analysis.

7.3.2 Results

The exposure scores are shown in Table 7-3.

<table>
<thead>
<tr>
<th>Task</th>
<th>Exposure scores for each assessment item</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Back</td>
</tr>
<tr>
<td>VDU work</td>
<td></td>
</tr>
<tr>
<td>Subject 1</td>
<td>22</td>
</tr>
<tr>
<td>Subject 2</td>
<td>22</td>
</tr>
<tr>
<td>General office work</td>
<td>20</td>
</tr>
</tbody>
</table>

The assessment showed that both VDU operators had a similar level of exposure, but their job had a higher level of exposure than that of general office work. Previous studies have found that people working at a VDU for most of the day tend to have a higher rate of musculoskeletal problems than those in reference groups who perform general office work and spend less time working on a computer (eg. Hunting et al., 1981; Smith et al., 1980, 1981). This field study indicated that the tool was sufficiently sensitive to ‘measure’ the difference between the job exposures of the regular VDU users and the general office worker.

Assessment validity of the exposure tool

To test the validity of the exposure tool, video recordings were analysed in both normal and slow playback speed, and the frames were 'frozen' when necessary for the measurement of body angles from the television screen. Video analysis was based on the definitions in the exposure tool and its corresponding assessment items. The results of the video analysis were then compared with the results of the exposure assessment obtained from the field studies using the exposure tool. This was to identify whether the practitioner's assessment on each item (eg. back posture or wrist/hand movement) would agree with the video analysis for the same item. The result showed a 78.6% overall agreement between field assessment with the exposure tool and the video analysis for the three types of jobs (i.e., stone pitching, laboratory work and VDU/office work).
7.4. EXPOSURE ASSESSMENT FOR JOBS IN THE WAREHOUSE AND THE SUPERMARKET

7.4.1 Tasks

Field tests of the exposure tool were also carried out in two very large retail organisations with a variety of jobs in the warehouse, kitchen and supermarket workplace. A wide range of tasks were observed/assessed, such as “trolley unloading and bag/box stacking”, “supermarket checkout”, “kitchen work” (e.g., cooking and food preparation, meat cutting, cleaning ovens, loading/unloading dishwasher), “office work” (VDU use), “picking in warehouse”, “unloading goods from lorry”, “box handling”, “box re-filling”, “shelf filling”, “packing items” etc. Thirty-two tasks in total were assessed by five practitioners (all were females) in five locations of the company, i.e., tasks 1-3 were assessed by practitioner No.1, tasks 4-8 were assessed by practitioner No.2, tasks 9-22 were assessed by practitioner No.3, tasks 23-27 were assessed by practitioner No.4, and tasks 28-32 were assessed by practitioner No.5.

Prior to making job/task assessment, the practitioner(s) was given standardised training on how to use the exposure tool and how to make risk assessments on individual tasks within each job. The training took about 15-20 minutes to complete. The tasks were all recorded by a video camera for further analysis. After assessing the tasks in each location, the practitioners answered a questionnaire to obtain their opinions about the exposure tool. Exposure scores were later calculated for each assessment item (body parts) for each task.

7.4.2 Results

The results are summarised in Table 7-4, below.

7.5 ASSESSMENT ITEMS TESTED IN THE FIELD STUDIES

In order to ensure that all assessment aspects of the exposure tool were tested in the field studies, video recordings were analysed to see whether the tasks involved posture change or movement (forceful/non-forceful, repetitive/non-repetitive) of the relevant body parts. These showed that the majority of tasks assessed had covered the assessment aspects as specified by the tool (Table 7-5).

Video recordings of the 32 tasks were analysed/assessed by one researcher in the same way as described in section 7.3. Considering the tasks assessed previously as reported in sections 7.1-7.3, the total number of tasks analysed in this way was 59 (with one missing recording). The final results are given in Table 7-6.
<table>
<thead>
<tr>
<th>Task</th>
<th>Exposure scores for each assessment item</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Back</td>
</tr>
<tr>
<td>Trolley unloading and bag stacking</td>
<td>36</td>
</tr>
<tr>
<td>Checkout</td>
<td></td>
</tr>
<tr>
<td>Subject 1:</td>
<td>24</td>
</tr>
<tr>
<td>Subject 2:</td>
<td>34</td>
</tr>
<tr>
<td>Cooking and food prep.</td>
<td>16</td>
</tr>
<tr>
<td>Food prep. /meat cutting</td>
<td>20</td>
</tr>
<tr>
<td>Cleaning oven</td>
<td>12</td>
</tr>
<tr>
<td>Emptying dishwasher</td>
<td>8</td>
</tr>
<tr>
<td>Word proc.</td>
<td>20</td>
</tr>
<tr>
<td>Picking men's/children's ware</td>
<td>26</td>
</tr>
<tr>
<td>Handling/unloading goods</td>
<td>36</td>
</tr>
<tr>
<td>Unloading beds</td>
<td>30</td>
</tr>
<tr>
<td>Unloading goods in lorry</td>
<td>36</td>
</tr>
<tr>
<td>Picking sports ware</td>
<td>30</td>
</tr>
<tr>
<td>Picking/hanging stock</td>
<td>22</td>
</tr>
<tr>
<td>Remove stock</td>
<td>32</td>
</tr>
<tr>
<td>Remove stock from rolling rail to picking rail</td>
<td>32</td>
</tr>
<tr>
<td>Unloading boxes onto pallet</td>
<td>30</td>
</tr>
<tr>
<td>Dragging sofas/arm chair</td>
<td>42</td>
</tr>
<tr>
<td>Unload polished furniture</td>
<td>28</td>
</tr>
<tr>
<td>Putting away tote boxes</td>
<td>18</td>
</tr>
<tr>
<td>Filling tote boxes (shirt)</td>
<td>32</td>
</tr>
<tr>
<td>Task</td>
<td>Exposure scores for each assessment item</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Filling tote boxes (jog pants)</td>
<td>26  30  24  12  14</td>
</tr>
<tr>
<td>Shelf filling (yoghurts)</td>
<td>30  38  40  18  18</td>
</tr>
<tr>
<td>Shelf filling (washing powders etc.)</td>
<td>42  46  42  18  14</td>
</tr>
<tr>
<td>Shelf filling (banana)</td>
<td>34  34  22  8  3</td>
</tr>
<tr>
<td>Checkout Conveyor</td>
<td>24  34  40  14  11</td>
</tr>
<tr>
<td>Checkout (basket)</td>
<td>26  40  46  18  3</td>
</tr>
<tr>
<td>Unload cage</td>
<td>34  34  34  8  14</td>
</tr>
<tr>
<td>Shelf filling (eggs/cakes)</td>
<td>26  34  30  14  3</td>
</tr>
<tr>
<td>Mile filling</td>
<td>26  18  24  6  3</td>
</tr>
<tr>
<td>Packing items for customer</td>
<td>38  26  30  4  3</td>
</tr>
<tr>
<td>Packing items to car</td>
<td>34  26  26  6  3</td>
</tr>
</tbody>
</table>
7.6 PRACTITIONERS' VIEWS ON THE EXPOSURE TOOL

In the field studies, six practitioners in total have used the exposure tool. For the question "How easy or difficult do you find the use of the exposure assessment tool?" (1=very difficult, 4=adequate, 7=very easy), the practitioners marked their answers on a 7-point bipolar scale (1=very difficult, 4=adequate, 7=very easy). Their mean rating was 5.53 (Median=5.2, SD=0.82, Range=4.9-7.0).

For the question "In general, how applicable do you find the tool to the work situations you have assessed?" (1=very poor, 4=adequate, 7=very good), the mean rating was 4.73 (Median=4.75, SD=1.23, Range=3.0-6.0).

For the question "Would this assessment tool be of value to you in your work?" (1=not at all, 7=very much), their mean rating was 5.30 (Median=5.0, SD=1.0, Range=4.0-7.0).

7.7 DISCUSSION

7.7.1 Suitability of the tool

The exposure tool has been tested in the field studies with a wide range of practical tasks, including dynamic or static tasks, manual handling (lifting/pushing/pulling) or repetitive tasks, tasks performed in seated or standing positions, tasks with high or low hand force exertions, tasks performed with or without hand tools, tasks with high or low visual demand, and so on. In general, the characteristics of the tasks assessed have covered all aspects of the tool (Table 7-5). The tool was considered by the practitioners as better than 'adequate' for its use in these task situations (section 7.6). In fact, it was found that the practitioners were able to assess all these tasks using this tool. Although some tasks were found to be relatively more difficult to assess than others (due to some dynamic feature of the tasks, for example), the practitioners could complete their assessment without too much difficulty.

7.7.2 Simplicity of the tool

After using the tool in assessing different work situations, the practitioners rated the tool at about 5.5 on average, which is close to "very easy" on the 7-point rating scale. It was also found that almost every assessment could be completed within 10 minutes. This confirmed the previous findings from the experimental studies, suggesting that the current format of the exposure tool is simple enough for its potential users to use in the real work situations. The results also suggested that, with appropriate training (self-learning), better preparation for using the tool and for the identification of the tasks, the tool could be used with ease.

7.7.3 Ability of the tool to assess change in exposure and the measurement accuracy of the tool

There was no 'correct' answer regarding the actual exposure for each individual task that was assessed in the field studies. However, the agreements between the practitioners' assessments and the detailed video analysis were between 76% and 91% for most of the assessment items, indicating that the practitioners could determine the task exposure at an acceptable accuracy level using this tool. It was also found that the assessment accuracy was relatively lower for some assessment items, particularly for the back posture (54.2%), shoulder/arm movement (76.3%) and neck posture (76.3%). This suggested that there were difficulties in using this tool in some task situations, especially where tasks were of a dynamic nature with rapid but non-repetitive movement.
Table 7-5. Assessment items covered in the practical tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Assessment items covered in the tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Back</td>
</tr>
<tr>
<td></td>
<td>/arm</td>
</tr>
<tr>
<td><strong>Stone pitching tasks</strong></td>
<td></td>
</tr>
<tr>
<td>Stone handling</td>
<td>✓</td>
</tr>
<tr>
<td>Stone shaping</td>
<td>✓</td>
</tr>
<tr>
<td>Digging</td>
<td>✓</td>
</tr>
<tr>
<td>Tamping stone</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Laboratory work</strong></td>
<td></td>
</tr>
<tr>
<td>Washing sample</td>
<td>✓</td>
</tr>
<tr>
<td>Sorting sample</td>
<td>✓</td>
</tr>
<tr>
<td>Microscope use</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Warehouse / supermarket work</strong></td>
<td></td>
</tr>
<tr>
<td>Trolley unloading</td>
<td></td>
</tr>
<tr>
<td>&amp; bag stacking</td>
<td>✓</td>
</tr>
<tr>
<td>Supermarket checkout</td>
<td>✓</td>
</tr>
<tr>
<td>Food preparation</td>
<td>✓</td>
</tr>
<tr>
<td>Cooking/meat cutting</td>
<td>✓</td>
</tr>
<tr>
<td>Cleaning oven</td>
<td>✓</td>
</tr>
<tr>
<td>Emptying dishwasher</td>
<td>✓</td>
</tr>
<tr>
<td>Word processing at VDU</td>
<td>✓</td>
</tr>
<tr>
<td>Pick men’s/child’s ware</td>
<td>✓</td>
</tr>
<tr>
<td>Handle/unload goods</td>
<td>✓</td>
</tr>
<tr>
<td>Unload beds/mattresses</td>
<td>✓</td>
</tr>
<tr>
<td>Unloading goods in lorry</td>
<td>✓</td>
</tr>
<tr>
<td>Pick sports ware</td>
<td>✓</td>
</tr>
<tr>
<td>Picking/hanging stock</td>
<td>✓</td>
</tr>
<tr>
<td>Remove stock from hang rail in lorry to</td>
<td></td>
</tr>
<tr>
<td>rolling rail</td>
<td>✓</td>
</tr>
<tr>
<td>Remove stock from rolling rail to picking</td>
<td></td>
</tr>
<tr>
<td>rail</td>
<td>✓</td>
</tr>
<tr>
<td>Unload boxes to pallet</td>
<td>✓</td>
</tr>
<tr>
<td>Drag sofas/arm chairs</td>
<td>✓</td>
</tr>
<tr>
<td>Unload polished furnit.</td>
<td>✓</td>
</tr>
<tr>
<td>Putting away tote boxes</td>
<td>✓</td>
</tr>
<tr>
<td>Filling tote boxes (shirt)</td>
<td>✓</td>
</tr>
<tr>
<td>Fill tote boxes (jog pants)</td>
<td>✓</td>
</tr>
<tr>
<td>Shelf filling (several types of items/tasks)</td>
<td>✓</td>
</tr>
<tr>
<td>Unload cage</td>
<td>✓</td>
</tr>
<tr>
<td>Packing items</td>
<td>✓</td>
</tr>
</tbody>
</table>
Table 7-6 Agreement between practitioners’ assessments and video analysis
(6 practitioners, 59 tasks)

<table>
<thead>
<tr>
<th>Agree (%)</th>
<th>Back posture</th>
<th>Back motion</th>
<th>Shoulder posture</th>
<th>Shoulder motion</th>
<th>Wrist posture</th>
<th>Wrist motion</th>
<th>Neck posture</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>54.2%</td>
<td>91.5%</td>
<td>81.3%</td>
<td>76.3%</td>
<td>84.7%</td>
<td>83.1%</td>
<td>76.3%</td>
<td></td>
<td>78.2%</td>
</tr>
</tbody>
</table>

One of the possible reasons for the low agreement of back posture assessment was that one of the six practitioners (who assessed 20 manual handling tasks) almost always regarded a back flexion of less than 90° from the vertical as 'moderately flexed' rather than 'extremely flexed', resulting in a high level of disagreement between his/her field assessment and the detailed video analysis by the researcher.

This problem is considered to be solvable if additional training is given, with clearer explanation/understanding about the definitions of the assessment items. Further analysis with the results from five practitioners who received a 'standardised training' and assessed 32 tasks showed that the agreement on back posture was 64.5%. Another reason for this low level of agreement was that the 'worst event' for the back posture may happen in very short time during which the observers may not be looking at the worker therefore missed the recording. Shoulder/arm movement was found to be a difficult aspect to assess because this was easily confused with the movement of the hand/wrist. This assessment item needs to be improved with clearer instruction that enables the observers to determine the movement between the shoulder or upper arm and the hand/wrist. It is also suggested that the movement of the shoulder/arm and hand/wrist be assessed together as one item. Further studies are needed to test these proposals.

Despite the fact that, at the time when the field studies were conducted, it was difficult to introduce ergonomic interventions to the workplace, the potential sensitivity of the tool could also be tested to some extent by comparing the exposure scores between two tasks.

For example, in the 'stone pitching' tasks, exposure levels in 'work site B' were found to be generally higher than that in 'work site A' (Table 7-1). Video recordings and the site visit also showed that work conditions in 'work site B' was harder than that in 'work site A' (with heavier/bigger stones and steeper bank, for example). This might have explained why the workers working in 'work site B' were much younger than those working in 'work site A'. Similarly, differences in exposure could also be seen between two types of tasks of the same or similar task nature, such as unloading goods (tasks 10/11, Table 7-4), removing stock (tasks 14/15), supermarket checkout with conveyor or basket (tasks 25/26).

However, it must be noted that the current 'score system' is only hypothetical, as has been discussed in an earlier section. Further studies are needed to test the suitability and effectiveness of this system in real work situations, and more scientific evidence is required in support of an appropriate system.
8. CONCLUSIONS AND FURTHER WORK

Over the past two years of this research programme, a method has been developed for the assessment of exposure to risks of work-related musculoskeletal disorders.

The method has been largely developed through a process of participatory ergonomics, with some 200 practitioners being involved at different stages. This has led to a tool designed by and for practitioners, with expert facilitation and testing.

The method has been tested through a series of experimental/laboratory studies for its sensitivity, inter-/intra-observer reliability, usability, and measurement validity. Field studies were also conducted to test the usability and validity of the tool for a number of practical tasks. The tasks have covered a wide range of work activities, such as manual material handling, repetitive tasks, static or dynamic tasks, seated or standing tasks, and tasks with low or high visual demands.

Based on the results obtained so far, it can be concluded that this exposure tool is suitable to be used when assessing the change in exposure before and after an ergonomic intervention, and for the exposure comparison either between two or more people performing the same task, or between people performing different tasks. The exposure tool is also found to be practically reliable and applicable for a wide range of jobs. With a little practice before using this exposure tool, assessment can be completed within approximately ten minutes for each task.

Despite the advantages found, the studies have also suggested that improvements are needed, particularly for the assessment of the shoulder/arm movement and the wrist/hand movement. The question relating to “the hand force exerted” was also experienced by the workers as being difficult to determine in some situations and therefore needs further attention.

Training is believed to be important for the efficient use of the tool. “The guide to the use of the exposure assessment tool” should be further improved along with the improvement of the tool itself. It is suggested that, before making the risk assessment, the users of the tool should be prepared or equipped with some knowledge as to how a job should be ‘divided’ into several tasks so that each task could be assessed individually with the tool. It is also suggested that a short video programme or computer-based interactive package be produced. This might include, for example, the meaning of some terms used in the tool (with animated pictures); examples of some ‘real’ jobs/tasks and how these can be assessed with this tool; exercises for the tool users to practise, with some sample tasks (covering both dynamic and static features) and the users could then compare their answers with the answers generated by others. It is anticipated that the ‘measurement’ reliability of the tool will increase with frequent use of the tool and the build-up of experience/knowledge in making risk assessment.

The “score system” is, at this time, only a theoretical/hypothetical one, which is similar to those score tables used in some other methods. The major difference is that the present system considers the interaction and combination of different “risk factors” in order to reflect what is happening in real work situations. Epidemiological evidence is still not sufficient to fully support the pattern of the combinations between risk factors as is suggested in the present ‘score system.’ At this stage the current system serves as a compromise between the ‘known’ and ‘unknown’ concerning the ‘weighting’ and ‘interaction’ of the ‘risk factors’, and should only be taken as a reference. In addition, this system (which can also be regarded as a ‘proposed model’) is calling for a new field of research and it may take several years before a better understanding is arrived at.
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Li, G. and Buckle, P., 1997a, Current techniques for assessing physical exposure to work-related musculoskeletal risks. Ergonomics (in press)


### Quick Exposure Check for work-related musculoskeletal risks - QEC

<table>
<thead>
<tr>
<th>Job title:</th>
<th>Task:</th>
<th>Assessment conducted by:</th>
<th>Worker's name:</th>
<th>Date:</th>
<th>Time:</th>
</tr>
</thead>
</table>

#### Back

- **When performing the task, is the back**
  - A1: Almost neutral?
  - A2: Moderately flexed or twisted or side bent?
  - A3: Excessively flexed or twisted or side bent?

- **For manual handling tasks only: Is the movement of the back**
  - B1: Infrequent? (Around 3 times per minute or less)
  - B2: Frequent? (Around 8 times per minute)
  - B3: Very frequent? (Around 12 times per minute or more)

- **Other tasks: Is the task performed in static postures most of the time?**
  - B4: No
  - B5: Yes

#### Wrist/Hand

- **Is the task performed**
  - E1: With almost a straight wrist?
  - E2: With a deviated or bent wrist position?

- **Is the task performed with similar repeated motion patterns**
  - F1: 10 times per minute or less?
  - F2: 11 to 20 times per minute?
  - F3: More than 20 times per minute?

#### Shoulder/arm

- **Is the task performed**
  - C1: At or below waist height?
  - C2: At about chest height?
  - C3: At or above shoulder height?

- **Is the arm movement repeated**
  - D1: Infrequently? (Some intermittent arm movement)
  - D2: Frequently? (Regular arm movement with some pauses)
  - D3: Very frequently? (Almost continuous arm movement)

#### Neck

- **When performing the task, is the head/neck bent or twisted excessively?**
  - G1: No
  - G2: Yes, occasionally
  - G3: Yes, continuously
Questions to be answered by the worker

Name:                                      Job title:                                      Date:

● What is the maximum weight handled in this task?
  a1: Light (5 kg or less)
  a2: Moderate (6 to 10 kg)
  a3: Heavy (11 to 20 kg)
  a4: Very heavy (More than 20 kg)

● How much time on average do you spend per day doing this task?
  b1: less than 2 hours
  b2: 2 to 4 hours
  b3: more than 4 hours

● When performing this task (single or double handed), what is the maximum force level exerted by one hand?
  c1: Low (Less than 1 kg)
  c2: Medium (1 to 4 kg)
  c3: High (More than 4 kg)

● Do you experience any vibration during work?
  d1: Low (or no)
  d2: Medium
  d3: High

● Is the visual demand of this task -
  e1: Low? (There is almost no need to view fine details)
  e2: High? (There is a need to view some fine details)

● Do you have difficulty keeping up with this work?
  f1: Never
  f2: Sometimes
  f3: Often

● How stressful do you find this work?
  g1: Not at all
  g2: Low
  g3: Medium
  g4: High

Thank you for your co-operation.
# Table of Exposure Scores

## Exposure to the Back

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<tr>
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<th>B3</th>
<th>Score 2</th>
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## Exposure to the Shoulder/arm

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<th>D2</th>
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## Worker's evaluations

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Back: _______ Shoulder/arm: _______ Wrist/hand: _______ Neck: _______
A guide to the use of the exposure assessment tool

This exposure tool has been designed to assess the change in exposure to musculoskeletal risks before and after an ergonomic intervention. Before making the risk assessment, a preliminary observation of the job should be made for at least one work cycle. Record all information as listed at the top of the exposure tool form.

Exposure assessment for the back

Back posture (A1-A3)

The assessment for the back posture should be made at the moment when the back is most heavily loaded. For example, when lifting a box, the back may be considered under highest loading at the point when the person leans or reaches forward to pick up the load.

- The back can be regarded as “Almost neutral” (Level A1) if the person is seen to work with his/her back flexion/extension, twisting, or side bending less than 20°, as shown in Figure-A1.

![Figure-A1](image)

Figure-A1. The back is “almost neutral”

- The back can be regarded as “Moderately flexed or twisted” (Level A2) if the person is seen to work with his/her back flexion/extension, twisting or side bending more than 20° but less than 60°, as shown in Figure-A2.

![Figure-A2](image)

Figure-A2. The back is “flexed or twisted”

- The back can be regarded as “Excessively flexed or twisted” (Level A3) if the person is seen to work with his/her back flexion or twisting more than 60° (or close to 90°), as shown in Figure-A3.

![Figure-A3](image)

Figure-A3. The back is “excessively flexed or twisted”
Back movement (B1-B5)

- For manual material handling tasks, assess B1-B3. This refers to how often the person needs to bend, rotate his/her back when performing the task. Several back movements may happen within one task cycle.

- For tasks other than manual handling, such as sedentary work or repetitive tasks performed in standing or seated position, ignore B1-B3 and assess B4-B5.

Exposure assessment for the shoulder/arm

Shoulder/arm posture (C1-C3)

Assessment should be made when the shoulder/arm is most heavily loaded during work, but not necessarily at the same time as the back is assessed. For example, the load on the shoulder may not be at the highest level when the person bends down to pick up a box from the floor, but may become greater subsequently when the box is placed at a higher level (Figure-C2).

![Diagram](image)

(1) Work at chest height

(2) Work at or above shoulder height

Figure-C. Assessment of shoulder/arm posture

Shoulder/arm movement (D1-D3)

The movement of the shoulder/arm is regarded as:

- "Infrequent" if there is no regular motion pattern.
- "Frequent" if there is a regular motion pattern with some short pauses.
- "Very frequent" if there is a regular continuous motion pattern during work.
Exposure assessment for the wrist/hand

Wrist/hand posture (E1-E2)

This is assessed during the performance of the task at the point when the most awkward wrist posture is adopted, include wrist flexion/extension, side bending (ulnar/radial deviation) and rotation of the wrist around the axis of the forearm. The wrist is regarded as “almost straight” (Level E1) if its movement is limited within a small angular range (e.g. <15°) of the neutral wrist posture (Figure-E1). Otherwise, if an obvious wrist angle can be observed during the performance of the task, the wrist is considered to be “deviated or bent” (Figure-E2).

![Figure-E1. The wrist is almost straight](image1)
![Figure-E2. The wrist is deviated or bent](image2)

Wrist/hand movement (F1-F3)

This refers to the movement of the wrist/hand and forearm, excluding the movement of the fingers. One motion is counted every time when the same or similar motion pattern is repeated over a set period of time (e.g., 1 minute).

---

Exposure assessment for the neck

The neck can be considered to be “excessively bent or twisted” if it is bent or twisted at an obvious angle (or more than 20°) relative to the torso.

---

Worker’s assessment of the same task

After the observer’s assessment is made, ask the worker to answer the questions as shown on the second page of the tool. Explain the meaning of the terms to him/her when necessary.

---

Calculation of the total exposure scores

The total exposure scores can be obtained by combining the assessments from the ‘observer’ and the ‘worker’. Ensure that the correct combined scores have been determined before adding them into the total.

Additional points:
- For group work, ensure a sufficiently representative number of individual workers are assessed.
- Workers whose daily pattern of work and job demands are variable, should be observed more than once.